# LAKE HURON 1980 INTENSIVE SURVEILLANCE:

# MANAGEMENT AND SUMMARY


by

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# PREFACE

During 1980, an intensive surveillance of Lake Huron was made which led to a wealth of information about the lake. Because few individuals can be expected to sift through all of the resulting published and unpublished documents, a summary document was prepared, which is Part 2 of this report.

Using information in Part 2 as justification, recommendations for the future management of monitoring of the lake are made in Part 1. In some cases, information from Part 2 is highlighted in Part 1 to justify recommendations.

This is the final report in a series of reports concerning the 1980 Lake Huron intensive surveillance, and published by the Great Lakes Research Division, The University of Michigan. The reports are as follows:


Rossmann, R., and T. Treese. 1982. Lake Huron bibliography with limited summaries. Spec. Rep. No. 88, Great Lakes Res. Div.

Rossmann, R. 1982. Trace metal chemistry of the waters of Lake Huron. Publ. No. 21, Great Lakes Res. Div.

Rossmann. R. 1983. Trace metals in Lake Huron waters - 1980 intensive surveillance. Spec. Rep. No. 97, Great Lakes Res. Div.

Evans, M. S. 1983. Lake Huron crustacean and rotifer zooplankton, 1980: factors affecting community structure with an evaluation of water quality status. Spec. Rep No. 98, Great Lakes Res. Div.

Moll, R. A., R. Rossmann, D. C. Rockwell, and W. Y. B. Chang. 1985. Lake Huron intensive survey, 1980. Spec. Rep. No. 110, Great Lakes Res. Div.

Kreis, R. G., Jr., and C. P. Rice. 1985. Status of organic contaminants in Lake Huron: atmosphere, water, algae, fish, herring gull eggs, and sediment. Spec. Rep. No. 114, Great Lakes Res. Div.

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# PART 1. MANAGEMENT RECOMMENDATIONS

## INTRODUCTION

Lake Huron is basically an oligotrophic lake, although it has at least one problem in common with the other Great Lakes: it is noticeably impacted by contaminants. A contaminant is anything that is introduced into a lake by man at a rate exceeding that which the lake is able to assimilate it without an alteration of the structure or quality of its ecosystem. The relative importance of each contaminant to all others is based upon our most recent perception of the criticality of its impact on the ecosystem. In the past, phosphorus, DDT, and mercury were the primary contaminants of concern because of the stimulation of nuisance algae growth, the negative impact on raptors, and the tainting of fish for human consumption, respectively. The responses to these discoveries have been control of the point sources of mercury and phosphorus and a ban on DDT production.

For Lake Huron, these controls appear to have been effective in curbing mercury releases but not in reducing mercury levels in fish. The controls appear to be beginning to be effective for phosphorus. The ban on DDT production appears to be responsible for observed decreases in DDT in Saginaw Bay fish, although concentrations in these fish are still high.

More recent concerns for the Lake Huron ecosystem have been with the levels of PCBs and other organic contaminants in fish for human consumption and in the quality of the ecosystem structure. The ecosystem includes not only sediment, water, bacteria, plankton, and fish but also the wildlife, especially birds, and the human population which is dependent upon the lake as a source of food and drinking water.

Thus monitoring activities must be designed to provide information needed for documenting changes in the ecosystem related to known contaminant inputs to the lake and for identifying new contaminants which need to be controlled. The earlier the detection and control of new contaminants, the less likely the lake will experience the kinds of chronic problems that it has experienced from inputs of phosphorus, PCBs, mercury, and DDT. Because of these and other needs which a monitoring program must address, it is necessary to develop a program that meets the basic needs without committing a disproportional share of available resources to a single need.

Saginaw Bay has not been able to assimilate phosphorus inputs without a measureable impact on its ecosystem. Past inputs of phosphorus to the bay stimulated the growth of nuisance algae (Stoermer et al. 1982). The reduction of nutrient loadings to the bay has virtually eliminated or reduced nuisance algae to less than 0.1% of the population and has reduced the abundance of all phytoplankton. This is an improvement in the quality of the bay's waters.

Soluble reactive phosphorus (Moll et al. 1985) and total phosphorous (Lesht 1985, Lesht and Rockwell 1985) appear to be decreasing in the offshore waters of Lake Huron. Because offshore Lake Huron phytoplankton species have always been those that are generally associated with oligotrophic waters, changes in the already low concentrations of phosphorus in the offshore waters have had little observable impact upon phytoplankton community structure or standing crop (Stevenson in press). Point sources of phosphorus still support growth of the nuisance attached alga Cladophora at Port Sanilac, Harbor Beach, Port Hope, Cheboygan, and St. Ignace, Michigan, and Goderich, Ontario. Additional efforts must be made to control point sources of phosphorus at these locations.

Sulfate and nitrate-nitrite concentrations continue to increase in the offshore waters of the lake (Moll et al. 1985, Kwiatkowski 1982). Neither of these has reached a concentration considered to be deleterious to the ecosystem. As long as phosphorus continues to be a limiting nutrient, the increasing nitrate-nitrite concentrations are not expected seriously to impact phytoplankton community structure in the near future.

In 1980, concentrations of PCBs, DDT, aldrin-dieldrin, and mercury in Lake Huron fish exceeded Water Quality Agreement objectives (Kreis and Rice 1985). Saginaw Bay fish had highest levels of PCBs. The sum of aldrin and dieldrin appeared frequently to exceed the IJC objective. Mercury concentrations in walleye continued to exceed the IJC objective, with no evidence of a decline. Concentrations of DDT in fish appeared to be decreasing. Phosphorus, PCBs, and DDT are the currently identified contaminants creating major acknowledged problems for the Lake Huron ecosystem. Dioxins and furans are an emerging problem in Saginaw Bay.

Dealing with the ever-growing list of contaminants which may impact the ecosystem is a basic problem which results from our inadequate knowledge of how contaminants are distributed and cycled within the ecosystem. Without this knowledge it is impossible to predict which compartment within the ecosystem will be impacted by a contaminant, what the severity of the impact will be, or what the probability of success will be for a proposed mitigative action. To gain this knowledge, a region of the lake should be chosen to serve as a case study for the remainder of the lake and all of the Great Lakes.

Saginaw Bay serves as an example of contaminant problems in the entire lake. The bay is impacted by a variety of contaminants, including phosphorus, PCBs, DDE, dioxins, DDT, and dieldrin. Recent data indicate the bay may be

improving with respect to nutrients; however, more data are necessary to confirm these changes. Relative to the lake, Saginaw Bay fish have high concentrations of PCBs and dioxin, gull eggs have high concentrations of PCBs and DDE, water has high concentrations of PCBs, and sediments have high concentrations of PCBs, DDT-R, and dieldrin (Kreis and Rice 1985). Atmospheric inputs of PCBs were highest near the bayhead. Because of this occurrence of a variety of contaminants, Saginaw Bay should be both routinely monitored and receive special emphasis to document the quality of its ecosystem, to monitor contaminant trends, and to assess effectiveness of control measures. The routine monitoring should be intensive and designed in a way that addresses the entire ecosytem (water, bacteria, sediment, phytoplankton, zooplankton, fish, benthos, and gulls) and the cycling of contaminants within it.

## MONITORING

### GENERAL REQUIREMENTS

In all of the recent reports on Lake Huron, there is one consistent problem. The data base for most measured parameters, especially metal and organic contaminants, is inadequate. Observations have been too infrequent to permit an assessment of long-term trends. Contaminants for which there is a recognized concern should be monitored yearly on a seasonal basis at a set of stations which are representative of the North Channel, Georgian Bay, northern Lake Huron, central Lake Huron, southern Lake Huron, and Saginaw Bay. Contaminants should be intensively studied using the ecosystem approach. This would provide a data base which describes not only year-to-year variations and within-year variability but also the impact of contaminants on the ecosystem.

## CONTAMINANTS

The current Lake Huron data base is inadequate for identifying emerging problems. In the case of organic contaminants, potential emerging problems can be identified by doing complete GC/MS analysis of fish, benthos, and sediments (Lake Michigan Task Force Report 1985). Any new anthropogenic compound or derivative found should be assessed for its potential to become an environmental problem. If it is perceived to be a problem, it should be added to the list of parameters monitored yearly on a seasonal basis. Monitoring for each organic and nutrient contaminant should continue long enough to ascertain if it is an emerging problem for which control actions would have to be taken or to document the effectiveness of control actions.

Metal contaminants data are also poor. Little or nothing is known about seasonal variations, year-to-year variations, and depth variations. Initially, metals currently of concern should be monitored yearly on a seasonal basis with collections from varying depths. Those metals which are known to accumulate in sediments and remain essentially as deposited should be monitored once every 10 years using Pb-210 dated sediment cores. When the variability of each metal of concern is understood, only those dissolved and particulate metals which are not preserved in the sediments should be monitored routinely. Because of the relatively high cost of monitoring metals and organic contaminants, a select few stations should be initially monitored.

## EXECUTION OF MONITORING RECOMMENDATIONS

To monitor the status of Lake Huron adequately, two interrelated programs must be simultaneously executed. The first program is a yearly monitoring plan for all of Lake Huron. Two cruises per year would be sufficient. These must occur during spring iso-thermal conditions (April-May) and well-developed summer thermal stratification (August-September). The intensity of sampling for each region of the lake should be adequate to permit statistical treatment of the data. Particular attention should be paid to select stations in the center of those persistent water masses described by Moll *et al*. (1985). This method of selection will considerably decrease the number of stations necessary for the monitoring of the lake compared to the number proposed by the Lake Huron Task Force (1984). This reduction will permit the use of available resources in the second program.

The second program would interface with the sampling periods of the first. It would be an intensive study of Saginaw Bay using the ecosystem approach. The ecosystem is used here not only to refer to each compartment (sedments, water, bacteria, phytoplankton, zooplankton, benthos, fish, man, air), but more importantly to the interactions of compartments. Such an approach would lend to an understanding of the pathways of contaminants within the ecosystem and to a general understanding of the mobility of classes of contaminants within the ecosystem. Currently, Saginaw Bay is an excellent choice for such a study because it has been intensively studied in the past, it is in an apparent state of change (phosphorus and DDT levels are declining) which provides differences that are measurable with current methodology, and it receives a variety of contaminants from industrial and municipal dischargers.

The design of any sampling program for the bay must be preceeded by a complete summary of all previous work. Many of the available data for the bay have not been adequately summarized and interpreted in the context of an ecosystem approach. With the results of such a summary and using ideas contained within the framework of the IJC Lake Huron Task Force Report (1984), a plan could be developed for a comprehensive study of the bay for the purpose of understanding the dynamics of the ecosystem and the behavior and impact of contaminants introduced into it.

Though similar in many respects, the general monitoring plan developed here differs in a number of ways from that developed by the Lake Huron Task Force (1984). For the open lake, both plans use an ecosystem approach whereby compartments of the ecosystem are measured and interrelated where possible. Each plan calls for sampling most compartments of the ecosystem during spring and summer. The major difference is the number and location of stations. The IJC Lake Huron Task Force proposed that 95 stations be monitored. The plan presented in this document calls for five regions of the lake to be monitored using the water mass approach of Moll et al. (1985). During the year, there are geographic regions of the lake which consistently are represented by a single water mass during each period of sampling. The overlap of water masses from cruise to cruise can be used to define the region to be sampled which will be representative of a particular geographic region of the lake. This approach would reduce the number of stations sampled to between 15 and 50. The exact number of stations to be sampled within each region is not known at this time. It would be dependent upon the desired statistical power with which changes could be discerned. Parameters to be monitored would be selected based upon need. However, using more than one parameter to achieve a particular purpose would be an inappropriate use of available resources.

For Saginaw Bay, the two plans differ significantly. The IJC Lake Huron Task Force proposed sampling does not appear to take the ecosystem approach, as defined in this document; whereas, the recommendations made by the author stress the ecosystem approach in the broadest sense. The major point of difference is a lack of stress on interrelating compartments of the ecosystem by the Task Force. This is essential to understanding the cycling of contaminants within the ecosystem. The Lake Huron Task Force plan utilizes 18 stations sampled during seven or eight cruises. The approach given here calls for a thorough review of all published and unpublished data and consideration of the ecosystem approach, as defined here, before station locations and the number of cruises are chosen. These should be chosen to emphasize the impact on and cycling of contaminants within the ecosystem.

# PART 2. SUMMARY

## INTRODUCTION

The Laurentian Great Lakes form the largest reservoir of fresh water on the earth. Based on surface area, Lake Superior is the second, Lake Huron is the fifth, Lake Michigan is the sixth, Lake Erie is the twelfth, and Lake Ontario is the fourteenth largest lake in the world (Hough 1958). The lakes are heavily utilized for industry, commerce, recreation, drinking water, and the disposal of wastes. The disposal of wastes is threatening the quality of Great Lakes water and fish. Water quality has been degraded by inputs of nutrients (primarily phosphorus), metals, and organic compounds. In some regions of the lakes and their connecting channels, fish have been rendered inedible because of high mercury, dioxin, and PCB concentrations. Management of the Great Lakes to maintain or improve their quality is a problem requiring international cooperation. The United States and Canada share four of the Great Lakes and depend upon these lakes as a source of recreation, industrial water, and drinking water. To provide for a cooperative program to preserve the largest freshwater resource in the world, the United States and Canadian governments signed the 1972 Great Lakes Water Quality Agreement. This was followed by an updated agreement in 1978.

### WATER QUALITY AGREEMENT

The 1978 Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada calls for the restoration and maintenance of the biological, chemical, and physical integrity of the waters of the Great Lakes basin

ecosystem. One of the measures implemented to achieve the GLWQA goals is a coordinated surveillance and monitoring program to assess achievement of water quality objectives, to monitor the response of the lakes to control measures, and to identify emerging problems. This Great Lakes International Surveillance Plan (GLISP) was developed by the International Joint Commission's Surveillance Work Group of the Water Quality Board. The plan calls for the surveillance effort to address the two key issues of eutrophication and contaminants. During 1980, a 1-year survey of Lake Huron was undertaken to assess its current status and trends in water quality changes, identify emerging problems, and monitor the impact of mitigative strategies used to improve water quality.

The purpose of this section is to summarize and highlight the results of work done on Lake Huron during the 1980 year of intensive surveillance. Details of this work will not be presented. For complete details, the reader is referred to the cited literature. Throughout this document, various distinct geographic regions will be referenced; these include the North Channel, Georgian Bay, northern Lake Huron, central Lake Huron, southern Lake Huron, and Saginaw Bay.

## LAKE HURON OPEN LAKE SAMPLING DURING 1980

During 1980, six open lake cruises were made; three by the R/V *Limnos* and three by the R/V *Roger R. Simons*. The cruises occurred between the months of April and November (Appendix 1). The stations sampled during each cruise are listed in Appendix 2 and illustrated in Figure 1. Parameters measured on shipboard included: dissolved silica, nitrate-nitrite, ammonia, pH, alkalinity, dissolved oxygen, water temperature, Secchi disk, turbidity, specific conductivity, and soluble reactive phosphate.

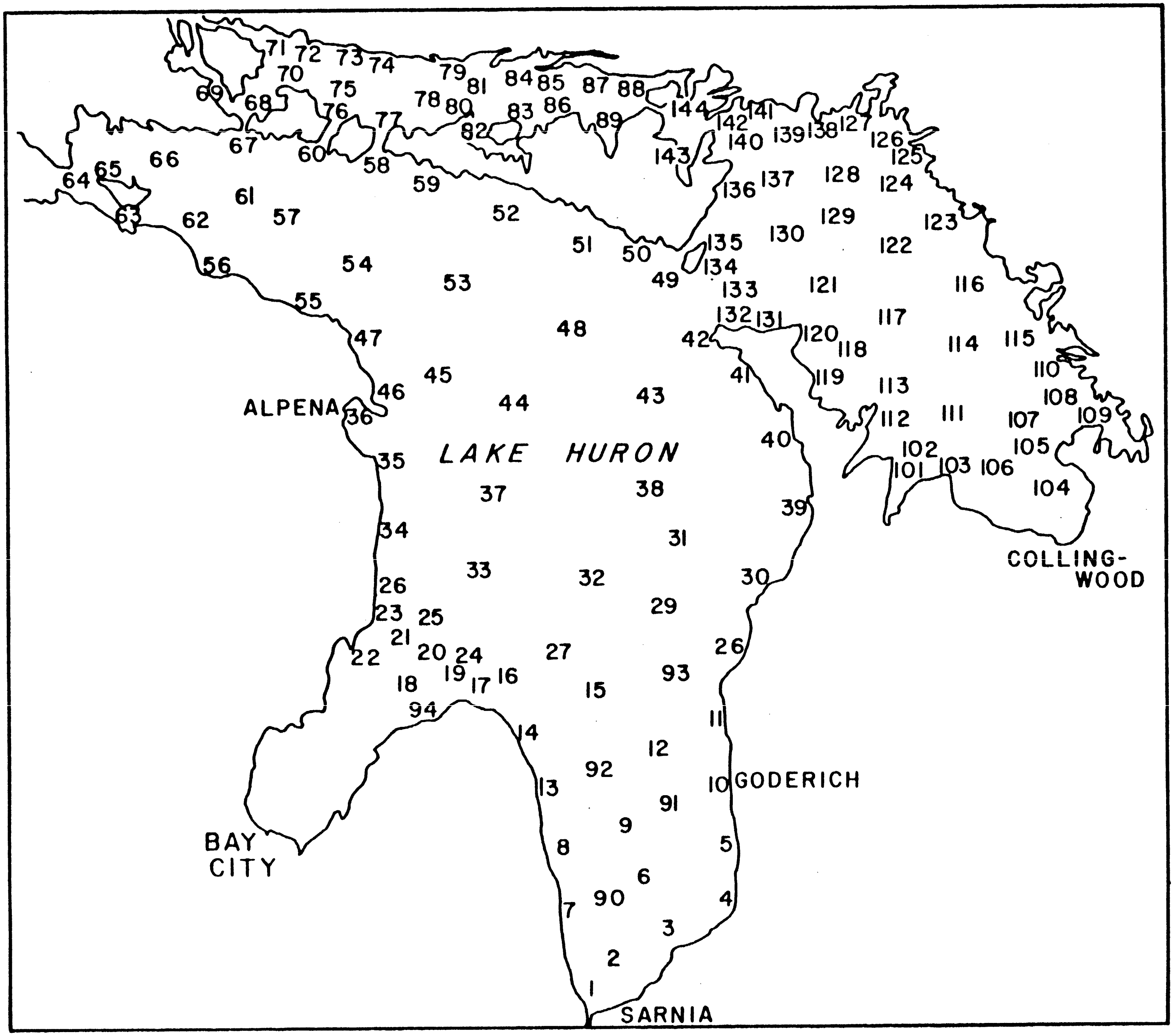



Figure 1. Lake Huron stations sampled in 1980.

Samples of the following were collected for laboratory analysis: sulfate, chloride, total phosphorus, total dissolved phosphorus, total Kjeldahl nitrogen, organic carbon, bacteria, phytoplankton, zooplankton, fish PCBs, calcium, magnesium, sodium, potassium, silver, aluminum, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium, arsenic, selenium, zinc, and mercury.

## PARTICIPANTS

To undertake a monitoring task of such a large magnitude, a diverse group of individuals affiliated with a large number of agencies or institutions was necessary for success. These participating agencies or institutions are listed in Table 1. Individuals whose works have been used in preparing this report are cited where appropriate in the text.

TABLE 1. Agencies and institutions participating in the 1980 intensive surveillance of Lake Huron.

| Agency |
|---|
| Argonne National Laboratory |
| Canada Centre for Inland Waters |
| Cranbrook Institute of Science |
| Great Lakes National Program Office, United States Environmental Protection Agency |
| International Joint Commission |
| Large Lakes Research Station at Grosse Ile, United States Environmental Protection Agency |
| Mar, Inc. |
| Michigan Department of Natural Resources |
| Ontario Ministry of the Environment |
| United States Fish and Wildlife Service |
| The University of Michigan |
| University of Minnesota |

# BIOLOGY

## PHYTOPLANKTON

During 1980, two studies of the Lake Huron phytoplankton were undertaken. The first of these was a study directed by Dr. E. F. Stoermer of the University of Michigan Great Lakes Research Division. His work concentrated on Saginaw Bay and southern Lake Huron. The second study was conducted by the United States Environmental Protection Agency Great Lakes National Program Office. This work included all of Lake Huron and was under the direction of the USEPA Great Lakes National Program Office. The majority of analyses were done by contract laboratory personnel in the USEPA Central Regional Laboratory. A few analyses were done at the University of Michigan Great Lakes Research Division under the direction of Dr. R. Rossmann and L. Feldt.

### Saginaw Bay

The 1980 Saginaw Bay results were compared with the results of 1974-1976 (Stoermer *et al*. 1983) by Stoermer *et al*. (1982). They found that there has been a major change in the phytoplankton community structure which is directly related to reductions in nutrient loading. These changes include: 1) near elimination of nuisance blue-green algae populations, including *Aphanizomenon flos-aquae* and *Anacystis cyanea*; 2) reduction to insignificance of algae populations associated with extreme eutrophication, including *Actinocyclus normanii* var. *subsulsa*; 3) a reduction in cell volume of the phytoplankton community; 4) a replacement of large-celled populations by smaller-celled populations; 5) a decrease in the average size of some populations common to the 1974-1976 and 1980 sampling periods; 6) significantly different phytoplankton associations

at the head of the bay due to loadings from the Saginaw River; 7) a population in the Saginaw River characteristic of contaminated rivers and adjacent near-shore areas; and 8) severely degraded water quality on the eastern Lake Huron shore (Stoermer *et al*. 1982). The changes and observations noted describe the bay as continuing to have water quality problems, although the overall trend in the water quality of the bay seems to be one of improvement.

## Southern Lake Huron

In the open waters of southern Lake Huron, the reduction of nutrient loading to Saginaw Bay is evident in both the abundance and composition of phytoplankton. Nuisance algae have been eliminated or reduced to less than 0.1% of the population. These include *Anabaena flos-aquae*, *A. subcylindrica*, *Aphanizomenon flos-aquae*, *Oscillatoria retzii*, *Gloeotilia* sp. (green filament #5), *Mougeotia* sp., *Phacotus lenticularis*, and *Actinocyclus normanii* var. *subsalsa*. Eurytopic populations indicative of Saginaw Bay waters are still present but reduced in abundance and range of occurrence (Stoermer *et al*. 1982).

Based on multivariate analysis of the 1980 results, Stoermer *et al*. (1982) partitioned southern Lake Huron into five regions. Three of the regions are nearshore and are as follows: 1) a region north of Saginaw Bay; 2) a region south of Saginaw Bay, less extensive in 1980 than 1974, characterized by two stations from the region having a clear connection with Saginaw Bay flora; and 3) a region along the Canadian coast distinguished by some eurytopic dominant species. The two offshore regions are: 1) an eastern offshore region characterized by low abundance oligotrophic populations, which occupied a larger region of the lake than in 1974; and 2) a northwestern region similar to the eastern offshore region but having an admixture of northern Michigan coast nearshore populations.

Lake Huron

For all of Lake Huron in 1980, Stevenson (in press) concluded that the phytoplankton found were those generally associated with oligotrophic waters. He found that phytoplankton were dominated by eurytopic diatoms throughout the year. Abundances and biovolumes were not large during the spring, biovolumes were low for the summer, and abundances increased only slightly in the fall. Blue-green algae were never abundant.

Regionally, Stevenson concluded waters were most enriched where greater standing crops of algae were found. These were found in the nearshore waters of southern Lake Huron, along the western shore, and near Cheboygan. Those along the western shore and near Cheboygan were more persistent than elsewhere. Relatively low standing crops were found for Georgian Bay.

Compared with previous years, the 1980 phytoplankton of Lake Huron were little changed. For southern Lake Huron, the loading of nutrients to the lake was responsible for the continued enrichment and degradation of its waters. A decrease in 1980 standing crops relative to the past near Saginaw Bay indicated a reduction in the loading of nutrients to the bay.

Using limited data from five stations in Lake Huron, Georgian Bay, and the North Channel, David DeVault (personal communication, Great Lakes National Program Office, USEPA) found that the phytoplankton biomass ranged from 0.3 to 3.2 $g/m^3$ for April through November 1980. This is within the oligotrophic range given by Vollenweider (1968). Diatoms, comprising between 43 and 97 percent of the total biomass, were the major contributors to biomass at these stations. On both cruises 3 and 6, southern Lake Huron had larger absolute and relative abundances of eurytopic and mesotrophic species than were found in the north. Eutrophic species were found in low abundance at several nearshore stations in the southern portion of the lake.

CLADOPHORA

*Cladophora* is a nuisance alga. It grows as long strands attached to a solid substrate. During storms, it breaks off and washes up on shore where it decomposes, impairing the quality of beaches used for recreational purposes (Auer *et al*. 1982).

*Cladophora* growth is a nuisance at Port Sanilac, Harbor Beach, Port Hope, Cheboygan, St. Ignace, and Goderich. It has been reported at Port Huron, Lexington, Alpena, Sarnia, Kettle Point, Stoney Point, Grand Bend, Bayfield, Point Clark, Kincardine, Douglas Point, Southampton, Tobermorey, the eastern Bruce Peninsula, Wiarton, Owen Sound, Little Current, Manitoulin Island, Mary Ward Shoal in southern Georgian Bay, and Blind River. The areas of nuisance growth of *Cladophora* are usually, though not always, associated with point discharges of phosphorus (Auer and Canale 1981). It grows in a nearly symmetrical pattern adjacent to a nutrient source. At Harbor Beach, *Cladophora* growth started in early May, peaked in late June, declined through August, increased in September, and declined to the overwintering form in late September (Auer *et al*. 1982). Seasonal growth dynamics are regulated by light and temperature, with growth rate directly related to the distance from a point source of phosphorus, when present (Canale *et al*. 1982). At Harbor Beach, *Cladophora* occupies an area of 38,704 $m^2$ (Lekan and Coney 1982).

At the Mary Ward Shoals in southern Georgian Bay, limited amounts of *Cladophora* exist. In southern Georgian Bay, its growth appears nutrient limited, and *Cladophora* occurs only in regions receiving nutrient loadings. A modeling study to predict growth of *Cladophora* at Mary Ward Shoals led to a decision by the Ontario Ministry of the Environment Southwestern Regions to

advise against the discharge of treated sewage to this site (Jackson and Hamdy 1982).

At Cheboygan near the mouth of the Little Black River, nuisance growths of Cladophora have occurred for several years. Growth is limited to the region of shoreline influenced by the river's inputs (Horvath and Hartig 1981).

## ZOOPLANKTON

In 1980, open lake zooplankton samples were collected in Lake Huron, the North Channel, and Georgian Bay. Sampling occurred once per month during April, May, June, and July. Standing stocks of zooplankton were consistently larger in the Bayfield-Goderich and Harbor Beach-Lexington regions of southern Lake Huron. With monthly means ranging from 14,000 to 75,604 crustaceans/$m^3$, the standing stocks were characteristic of other oligotrophic or oligo-mesotrophic regions of the Great Lakes. Crustaceans dominated the zooplankton standing stocks. The 1980 crustacean community was dominated by Cyclops bicuspidatus thomasi, Diaptomus ashlandi, Diaptomus minutus, and Diaptomus sicilis (Evans 1983). In July 1980, Bosmina longirostris, Daphnia galeata mendotae, Daphnia retrocurva, and Eubosmina coregoni were important. Crustaceans appear to have increased in numbers between 1970 and 1975 and to have decreased slightly between 1975 and 1980. Evans cautioned that these differences may result from differing sample locations and methodologies.

In 1980, open lake rotifer standing stocks ranged from 4,541 to 14,993 individuals/$m^3$ and were indicative of oligotrophic conditions. Consisting of Notholca squamula, Synchaeta sp., Conochilus unicornis, Kellicottia longispina, and Keratella cochlearis cochlearis, the spring and summer species assemblages were characteristic of oligotrophic waters. Trichocera multicrinis occurred

at several stations in July in southern Lake Huron. This is considered an indicator of eutrophic conditions; however, it occurred in low abundance (Evans 1983).

## BENTHIC AND EPIPHYTIC INVERTEBRATES

### Thunder Bay, Michigan

Collection of benthic macroinvertebrates in August 1980 confirmed the trend of improved water quality noted in 1974-1975. Both the 1974-1975 and 1980 studies documented a more diverse and balanced benthic community, with organic pollution-tolerant forms becoming less dominant.

The Thunder Bay River mouth and Alpena Harbor benthic communities were dominated by oligochaetes, in particular, *Limnodrilus hoffmeisteri*. The Middle Bay community contained nearly equal numbers of oligochaetes (40%) and chironomids (39%). The oligochaetes were dominated by *Pelosiolex ferox* (20%) and *Stylodrilus heringianus* (5%), while the most abundant chironomid was *Heterotrissocladius* (19%). In the Outer Bay, the oligochaetes (primarily *Stylodrilus heringianus*) accounted for 52% of the benthos, and chironomids (primarily *Heterotrissocladius* and *Procladius*) accounted for 33% of the community (Horvath *et al*. 1981). The enriched region of Thunder Bay is within 1.6 kilometers of the Thunder River mouth and extends, with decreasing enrichment, a distance of 6.4 kilometers offshore (Horvath *et al*. 1981).

### Sturgeon Bay, Ontario

During June and July 1980, a survey to assess biological conditions of Sturgeon Bay near Waubeshene, Ontario, was conducted, prior to the installation of a waste water treatment plant. Results revealed a water quality that appears

to be good. The bay supported a fauna typical of a shallow, weedy bay in the Great Lakes area. Plant cover in the bay was heterogeneous (1-100%), with Myriophyllium being the dominant or co-dominant at most stations. Chironomidae, Naididae, Gastropoda, and Malacostraca were the dominant groups of macroinvertebrates in plant samples; and Nematoda, Gastropoda, Pelycepoda, Malacostraca, Chironomidae, and Tubificidae were most common in the muds (Barton 1981).

BACTERIA

In 1981, samples for total and fecal coliforms and fecal streptococci, which are of public health significance, and aerobic heterotrophs, which are eutrophic indicator bacteria, were collected from Lake Huron. Between 1974 and 1980 in Lake Huron and the North Channel, fecal coliform and aerobic heterotrophic bacteria densities did not change; fecal streptococci bacteria densities increased slightly but not significantly. In Georgian Bay in 1980, fecal coliform densities were slightly less than those of 1974; and 1974 and 1980 fecal streptococci densities were similar (Rao and Jurkovic 1981). Comparing 1980 to 1974, aerobic heterotrophic bacteria densities decreased slightly near point source input areas such as Owen Sound, Parry Sound, and northeast Georgian Bay.

## BEACHES

The State of Michigan has 48 beaches on Lake Huron used for swimming. Of these, 22 were monitored during 1981. During both 1980 and 1981, two beaches were permanently closed. These were Bay View Beach at Alpena and St. Ignace Beach at St. Ignace. Bay View Beach was closed for esthetic reasons. A sawmill's wastes dumped 100 years ago are now surfacing. St. Ignace Beach was closed until correction of the combined storm and sanitary sewer system problems.

During 1980 and 1981, temporary closings occurred only at Lexington Beach near Sanilac. The closings were due to discharge of Lexington's waste water from the treatment lagoon to the lake.

## NUTRIENTS AND OTHER MEASURED PARAMETERS

### INPUTS

Between 1976 and 1980, the estimated phosphorus loadings to the lake have varied between 3,763 and 5,307 metric tons per year (Table 2). The highest estimated loading occurred in 1980. In 1980, atmospheric phosphorus loading to Lake Huron, excluding southern Lake Huron, was 283 metric tons per year with highest loading (76 metric tons per year) occurring in Saginaw Bay (Dolan 1982). Utilizing the wet sampler air data of Chan (1982), the estimated loading to Georgian Bay and the North Channel was 100 metric tons per year; estimates for 1977, 1978, and 1979 were 248, 162, and 216 metric tons per year, respectively.

TABLE 2. Estimated phosphorus loadings (1976-1980) to Lake Huron (metric tons/year).

| Year | Estimated Total Loading |
|---|---|
| 1976[1] | 4,802 |
| 1977[1] | 3,763 |
| 1978[2] | 5,255 |
| 1979[2] | 4,881 |
| 1980[2] | 5,307 |

[1]Great Lakes Water Quality Board (1977).
[2]Great Lakes Water Quality Board (1981).

Between 1974 and 1980, phosphorus loadings from the Saginaw River decreased at the rate of 322 metric tons per year. The loading in 1980 was 472 metric tons per year. For the years 1974-1980, no trends in total phosphorus concentration in Saginaw Bay could be discerned (Bierman et al. 1982).

In general, total phosphorus loading to Thunder Bay decreased between 1968 and 1978. A peak loading of 140 metric tons per year occurred in 1969. The loadings for 1979 and 1980 (65 metric tons per year) were similar to those of 1971 and 1972. Decreased loadings in 1974 and 1976 coincided with better phosphorus removal at waste water treatment plants; additional decreases between 1977 and 1978 coincided with the State of Michigan phosphorus detergent ban imposed in October 1977. Combined sewer separation is expected to decrease loadings further. Within Thunder Bay and the harbor, total phosphorus concentration declined slightly in 1980 relative to that of the late 1960s. In 1980, ammonia concentrations in the river and harbor were one-fourth those of the late 1960s. Nitrate concentrations were constant for the period of record for the river but increased in the harbor. Total Kjeldahl nitrogen and dissolved reactive silica have remained stable since 1974 and 1966, respectively (Horvath et al. 1981).

## OPEN LAKE

Two reports have been prepared which describe the results of the 1980 intensive surveillance year and compare them with historical data for the purpose of assessing trends. A different approach to assessing trends was taken in each report.

The first is an unpublished report prepared for the Water Quality Branch of the Inland Waters Directorate (Kwiatkowski 1982). He compared the 1980 data to those of 1971 for Lake Huron and 1974 for Georgian Bay-North Channel. Comparisons were based on dividing the lake into statistically homogeneous regions using a regression model developed by El-Shaarawi and Kwiatkowski (1977). Each established region is statistically different from all others at the 0.10 level of significance. Using these comparisons, Kwiatkowski noted significant increases in nitrate-nitrite (6 μg N/L per year) and dissolved silica in Lake Huron. The largest nitrite-nitrate increase occurred in southern Lake Huron. He noted significant increases in nitrate-nitrite (4 μg N/L per year) and significant decreases in total phosphorus and chlorophyll _a_ for Georgian Bay-North Channel. The input of St. Marys River and the North Channel upon northern Lake Huron is characterized by increased total phosphorus and dissolved silica concentrations. The impact of Lake Michigan on northern Lake Huron is described by decreased dissolved silica and nitrate-nitrite concentrations. In comparing nearshore versus offshore differences between 1980 and 1971, Kwiatkowski (1982) found that the differences were greater in 1980 than in 1971, especially in southern Lake Huron. He found that Saginaw Bay and the Sarnia-Goderich area each influence the water chemistry of southern Lake Huron. The input of the Sarnia-Goderich region upon the lake was most notable for nitrate-nitrite and chlorophyll _a_ and less notable for total phosphorus.

The second report prepared, which describes the 1980 intensive year results and compares them with historical data, is that of Moll _et al_. (1985). Two approaches were taken by the authors. Data from the summer months of 1954 to 1980 and spring months of 1971 to 1980 were used to calculate spring and summer long-term changes using polynomial regression (Table 3). The first approach

TABLE 3. Linear regression coefficients of variables with time derived from least squares analysis of spring and summer data.

| Variable | All Stations Spring (1971-1980) | One Water Mass Representing Southern Lake Huron Spring (1971-1980) | All Stations Summer (1954-1980) | One Water Mass Summer (1954-1980) | Epilimnion One Water Mass Summer (1954-1980) |
|---|---|---|---|---|---|
| Temperature °C/yr | 0.0898 | 0.144 | -0.0721 | -0.1350 | -0.0659 |
| Conductivity μmho/cm/yr | -1.845 | -0.436 | 1.10 | 1.6164 | 1.30 |
| Chloride mg/L/yr | -0.0622 | 0.0249 | -0.0608[1] | -0.0180[1] | -0.0370[1] |
| Sulfate mg/L/yr | n.s.[2] | 0.0518 | 0.116[1] | 0.12901 | 0.112[1] |
| Silica mg/L/yr | n.s. | n.s. | -0.0397 | -0.0418 | -0.0493 |
| Nitrate mg/L/yr | 0.0033 | 0.00888 | 0.00624[3] | 0.0066[3] | 0.00488[3] |
| Sol. P μg/L/yr | n.s. | n.s. | 0.0296[4] | 0.0690[4] | n.s.[4] |
| Total P μg/L/yr | n.s. | 0.153 | -0.0885[3] | n.s.[3] | n.s.[3] |

[1]1956-1980
[2]n.s. = not significant at 0.05 level of significance
[3]1968-1980
[4]1966-1980

used all data available for the spring or summer months. Dissolved silica increased from 1971 and 1976 and decreased after 1976.

The second approach by Moll et al. (1985) used the same data as the first approach. However, trends were compared for stations situated within homogeneous water masses. Cluster analysis was used to identify homogeneous water masses, and discriminant function analysis was used to confirm the statistical distinctness of one water mass from another within each year. The water masses utilized for each cruise are shown in Figures 2-7. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises. Polynomial regression was used to calculate changes within one water mass having the same general geographical location from month to month in 1980 and from year to year.

Spring - All Data

Least-squares regression was used to determine whether or not a significant linear trend existed for any of the eight variables between the years 1971 and 1980. Polynomial regression was used to calculate changes in variables that could be significantly represented by higher order curves.

Each figure that follows contains a plot of all data points with their associated significant (0.05 level of significance) time variation curves. With temperature and nitrate increasing and conductivity and chloride decreasing, temperature, conductivity, chloride, and nitrate had a significant linear trend (0.1 level of significance) (Table 3 and Fig. 8). Sulfate, soluble reactive silica, soluble reactive phosphorus, and total phosphorus had no significant long-term linear trend; but each had a significant curvilinear change (Fig. 8). Mean concentrations of sulfate decreased between 1974 and 1977 and increased after 1977. Those for silica increased between 1971 and 1976 and decreased

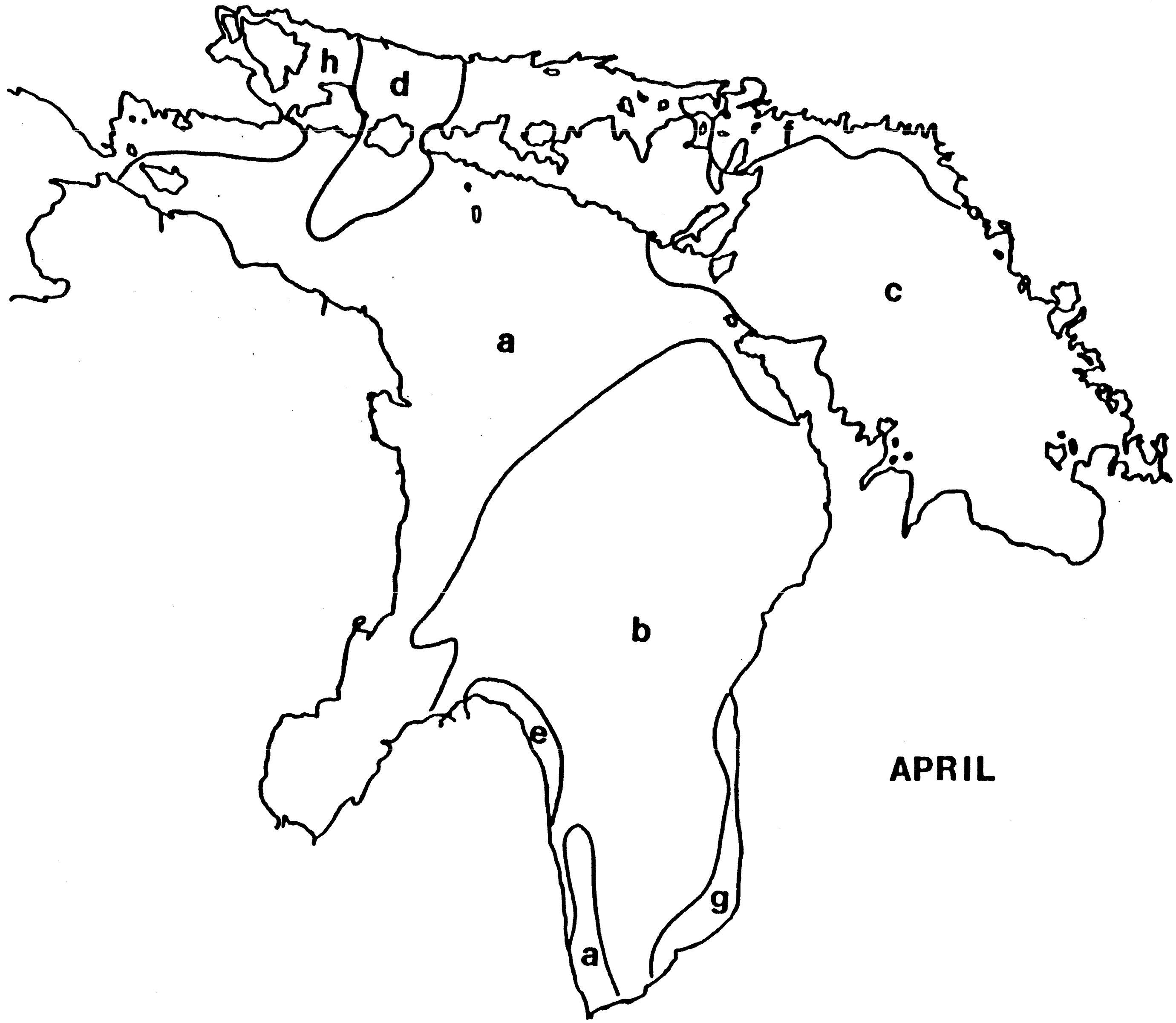



Figure 2. Homogeneous water masses in Lake Huron during Cruise One in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

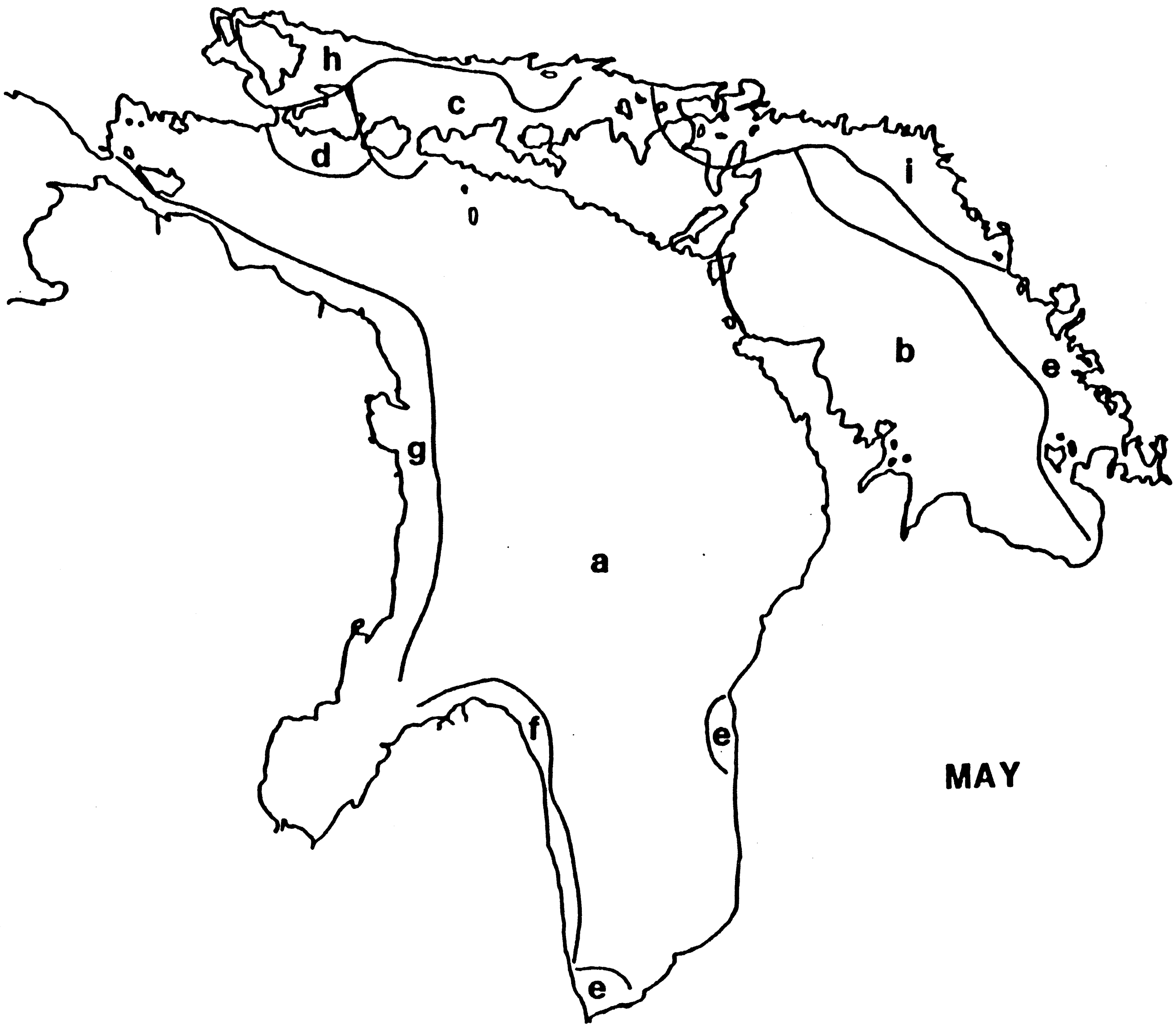



Figure 3. Homogeneous water masses in Lake Huron during Cruise Two in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

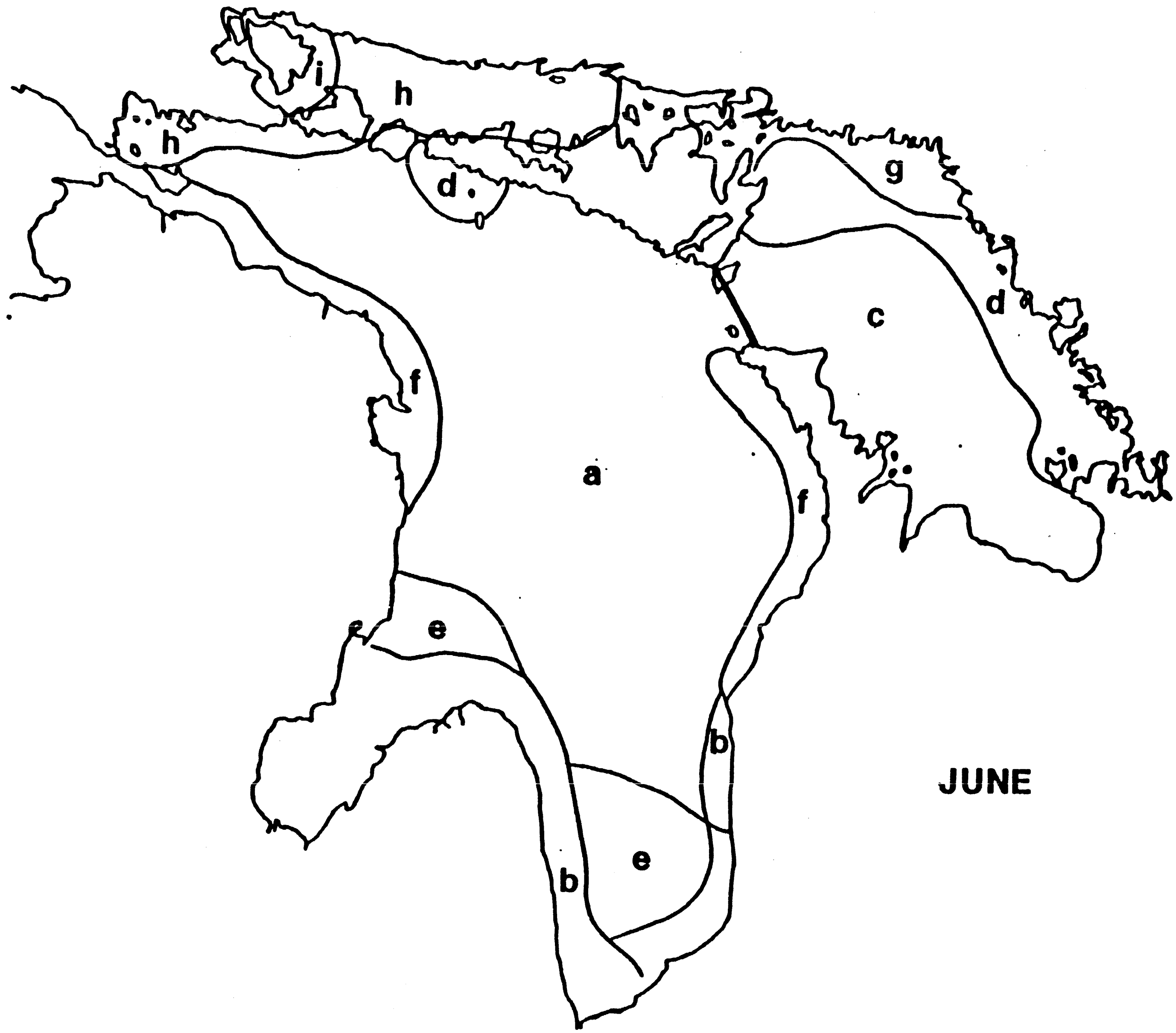



Figure 4. Homogeneous water masses in Lake Huron during Cruise Three in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

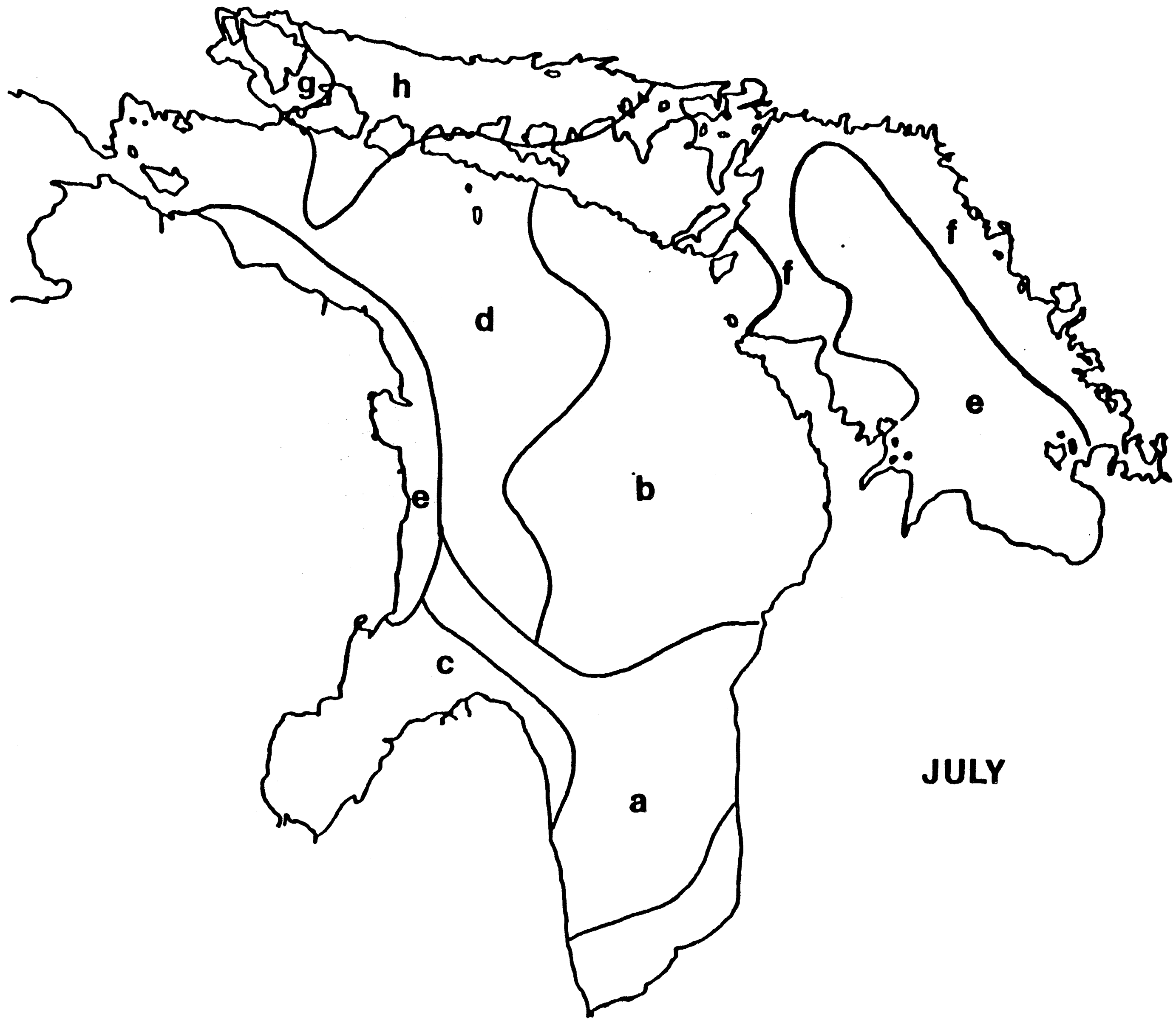



Figure 5. Homogeneous water masses in Lake Huron during Cruise Four in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

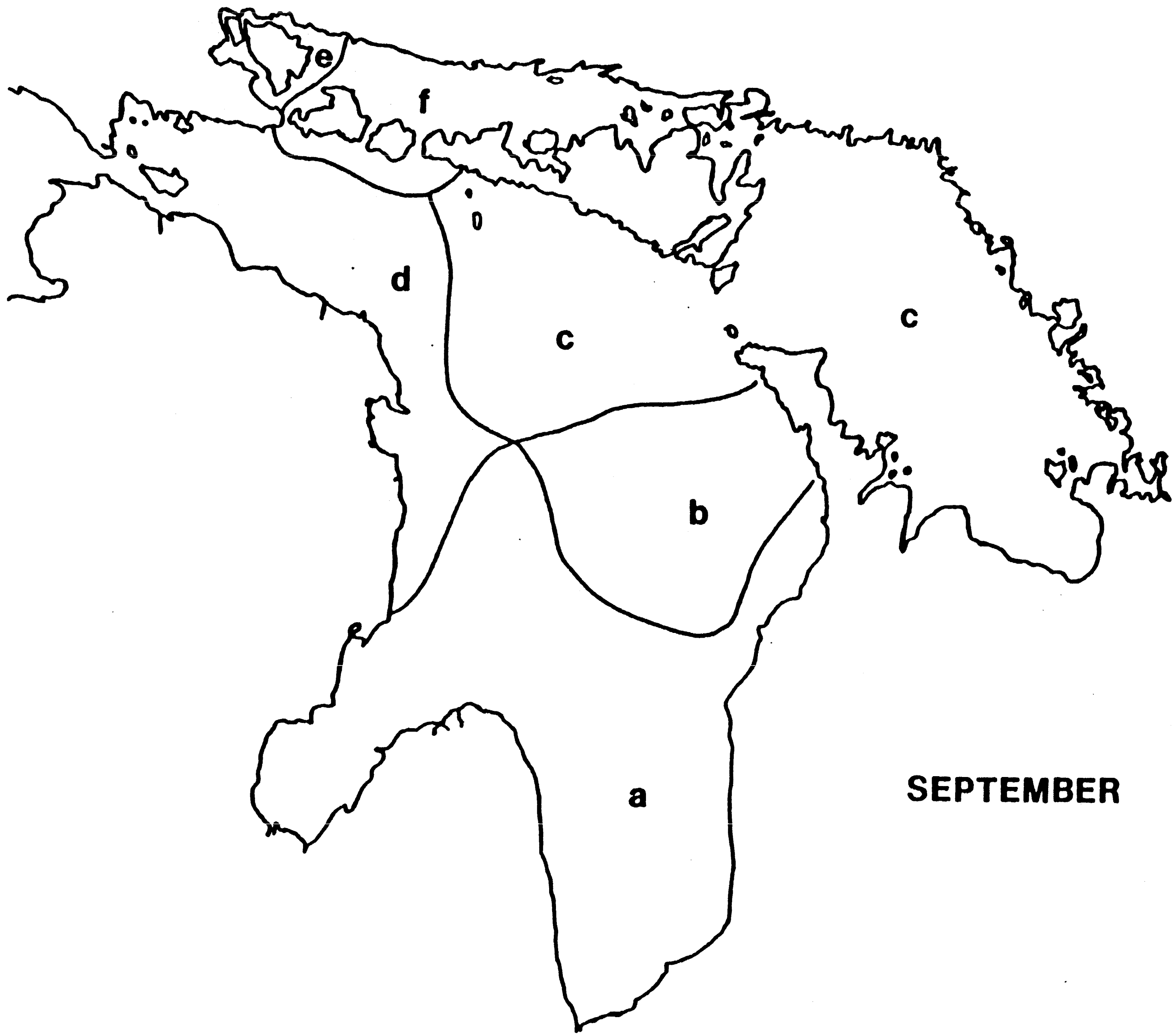



Figure 6. Homogeneous water masses in Lake Huron during Cruise Five in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

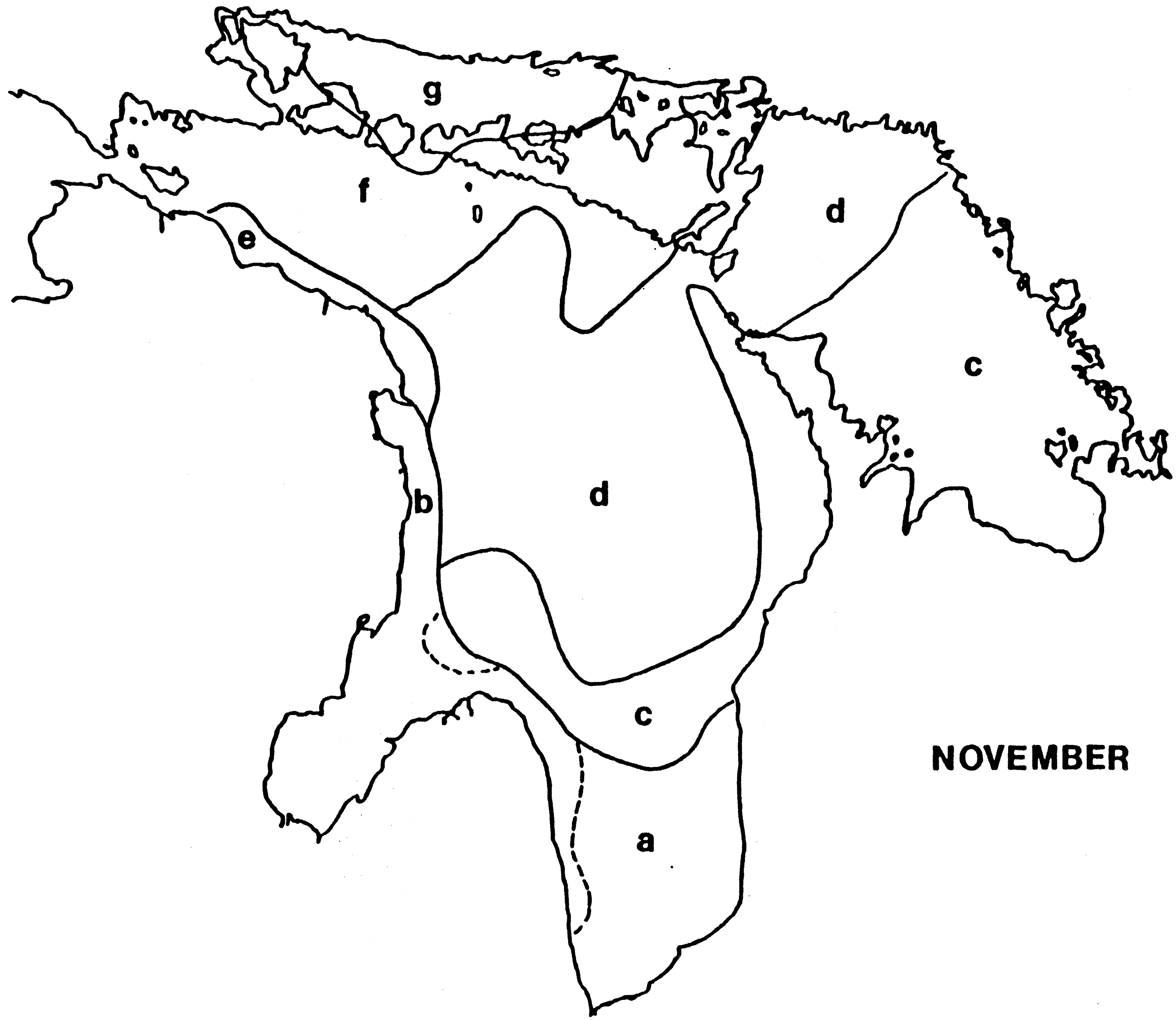



Figure 7. Homogeneous water masses in Lake Huron during Cruise Six in 1980. The lettering of water masses is for the purpose of presentation. A water mass labelled "a" for one cruise is not the same as the "a" for other cruises.

after 1976. Mean concentrations of soluble reactive and total phosphorus increased between 1971 and 1976 and decreased after 1976.

### Spring - One Homogeneous Water Mass

For each year "one water mass" was identified as representing open southern Lake Huron water quality (Moll *et al*. 1985). The regression analyses using the one water mass data were somewhat similar to the results using all spring data (Table 3). Nitrate and temperature continued to show an increasing trend, and conductivity showed a decreasing trend for both data sets. Unlike all of the spring data, one water mass data for sulfate and total phosphorus showed an increasing trend. Only chloride showed a major change in the regression coefficient using the one water mass data. In this case, a decrease was noted for all spring data, while an increase was found for the spring one water mass data. The difference may perhaps be due to the inclusion of data collected from the nearshore zone or to an emphasis on southern Lake Huron data in the second case. Six of the eight variables showed significant linear trends over the 10 years, with soluble phosphate and soluble reactive silica displaying no linear trend (Fig. 9). However, both displayed a curvilinear variation (Fig. 9). Both increased between 1971 and 1976 and decreased after 1976. All curvilinear fits displayed in spring for one homogeneous water mass resemble those shown in spring for the entire lake.

### Summer - All Data

Least-squares regression was also used to determine if a significant linear trend existed for the 1954 to 1980 period. With temperature, chloride, silica, and total P decreasing and conductivity, sulfate, nitrate, and soluble P increasing, all eight variables displayed a significant linear trend (Table 3,

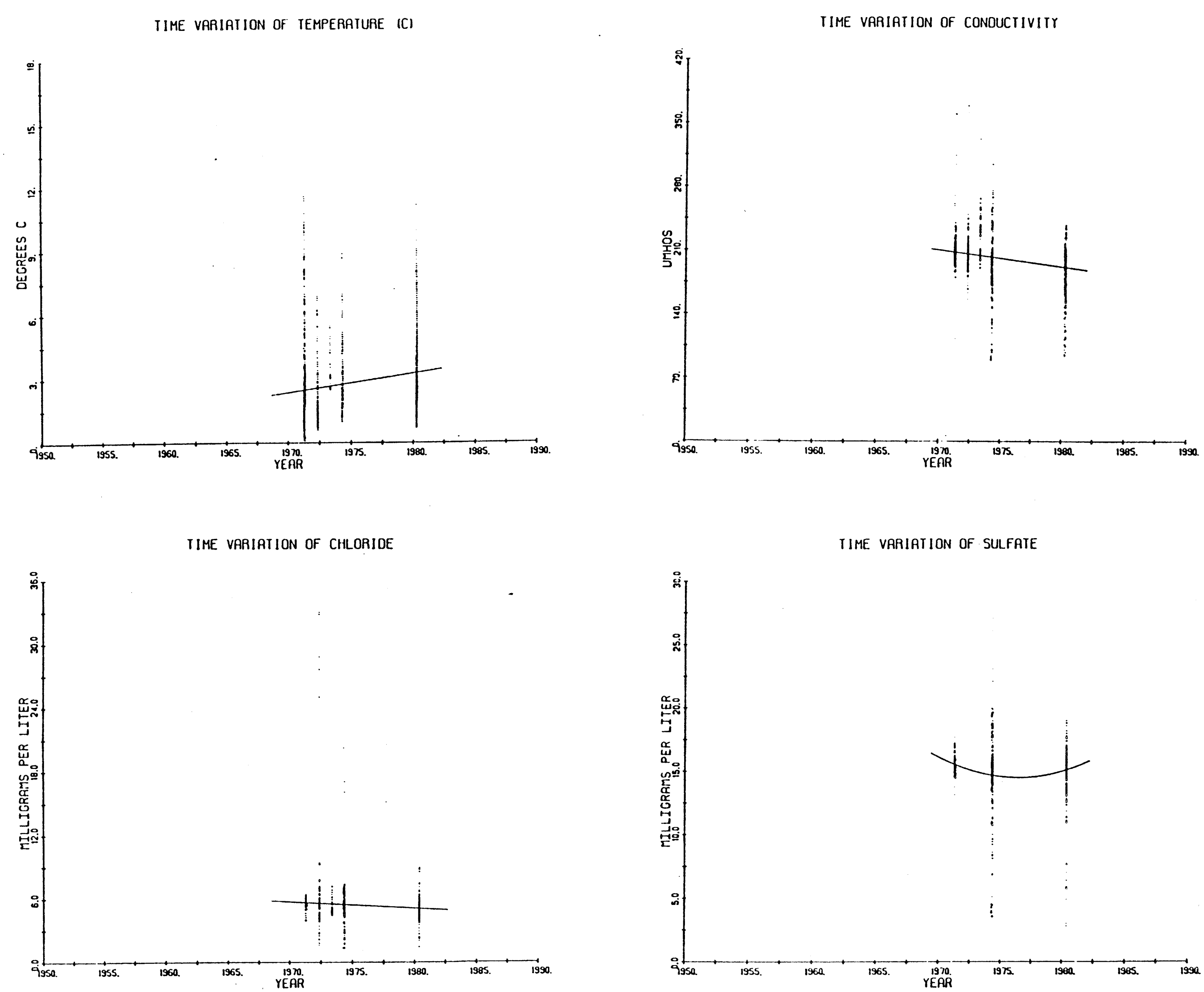



Figure 8. Spring time variation of parameters in Lake Huron water.

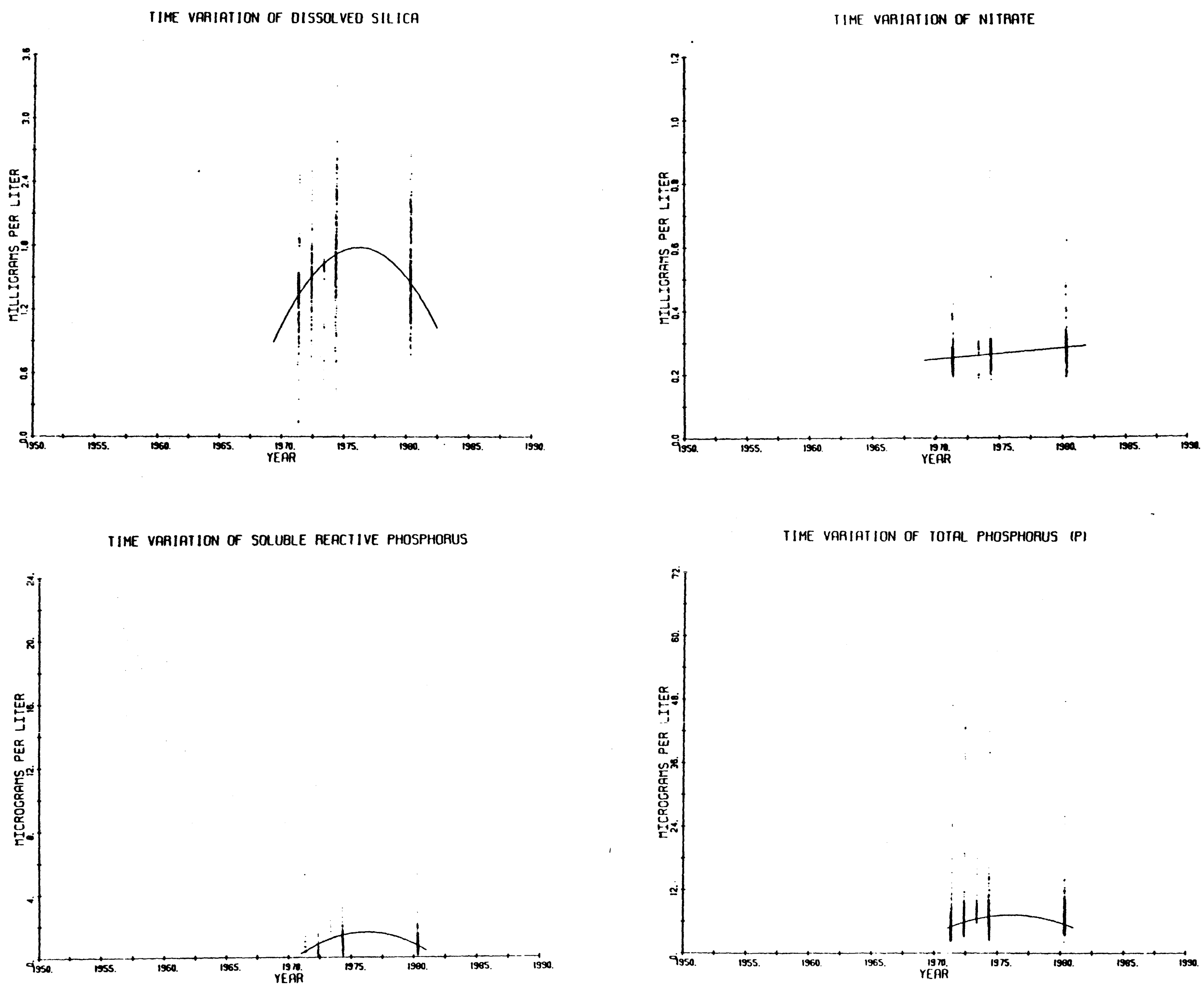



Figure 8. Concluded.

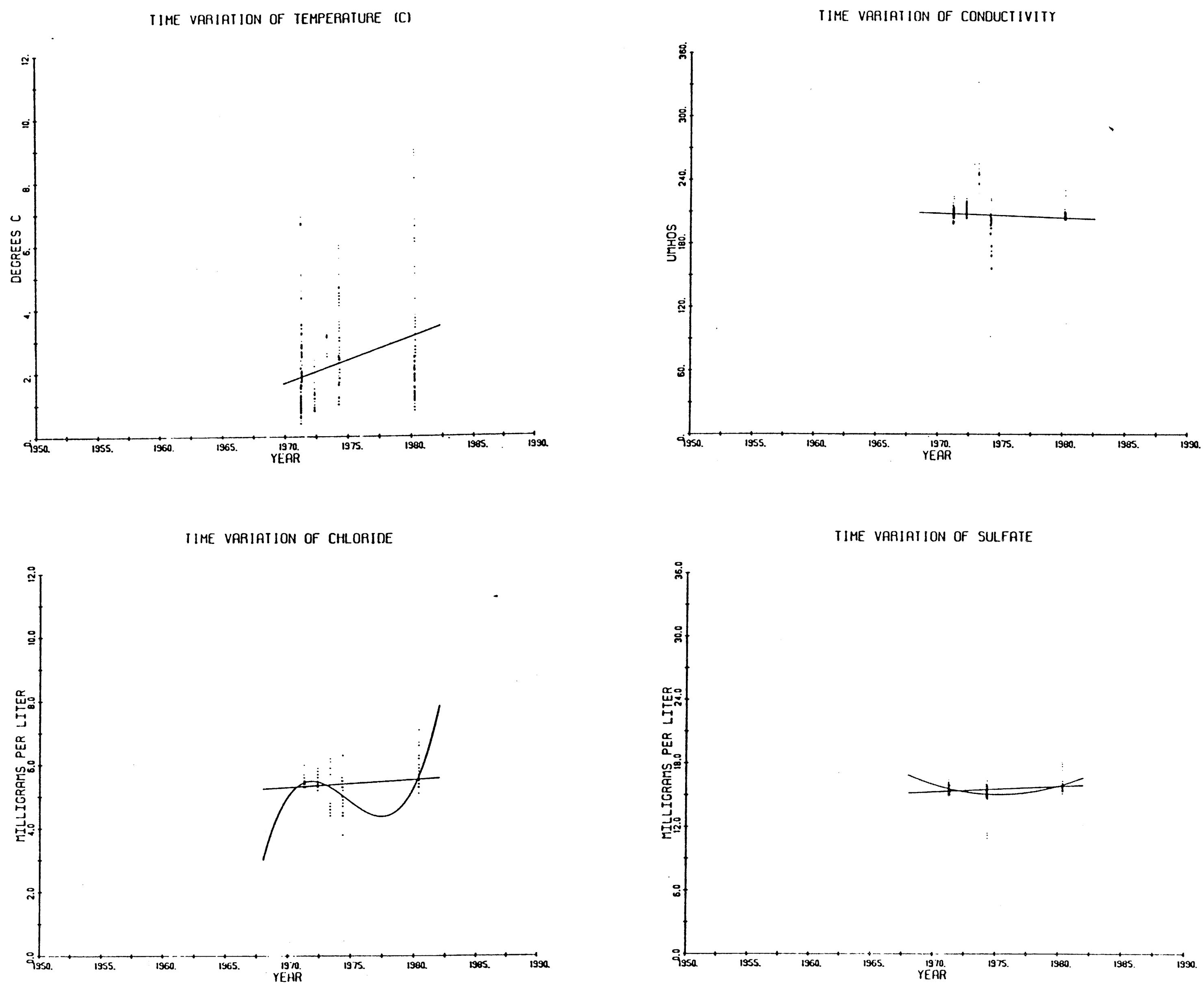



Figure 9. Spring time variation of parameters in one water mass of Lake Huron.

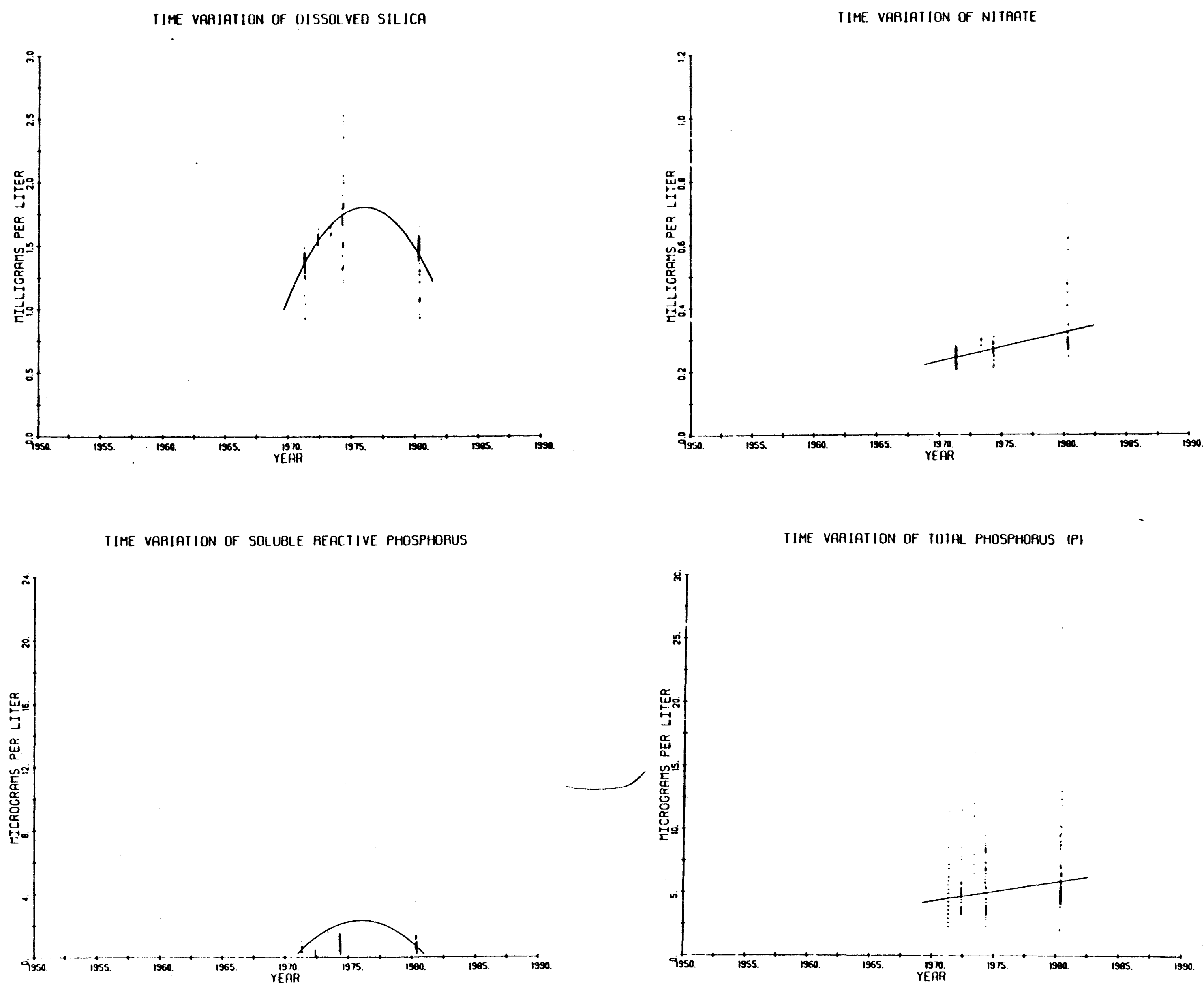



Figure 9. Concluded.

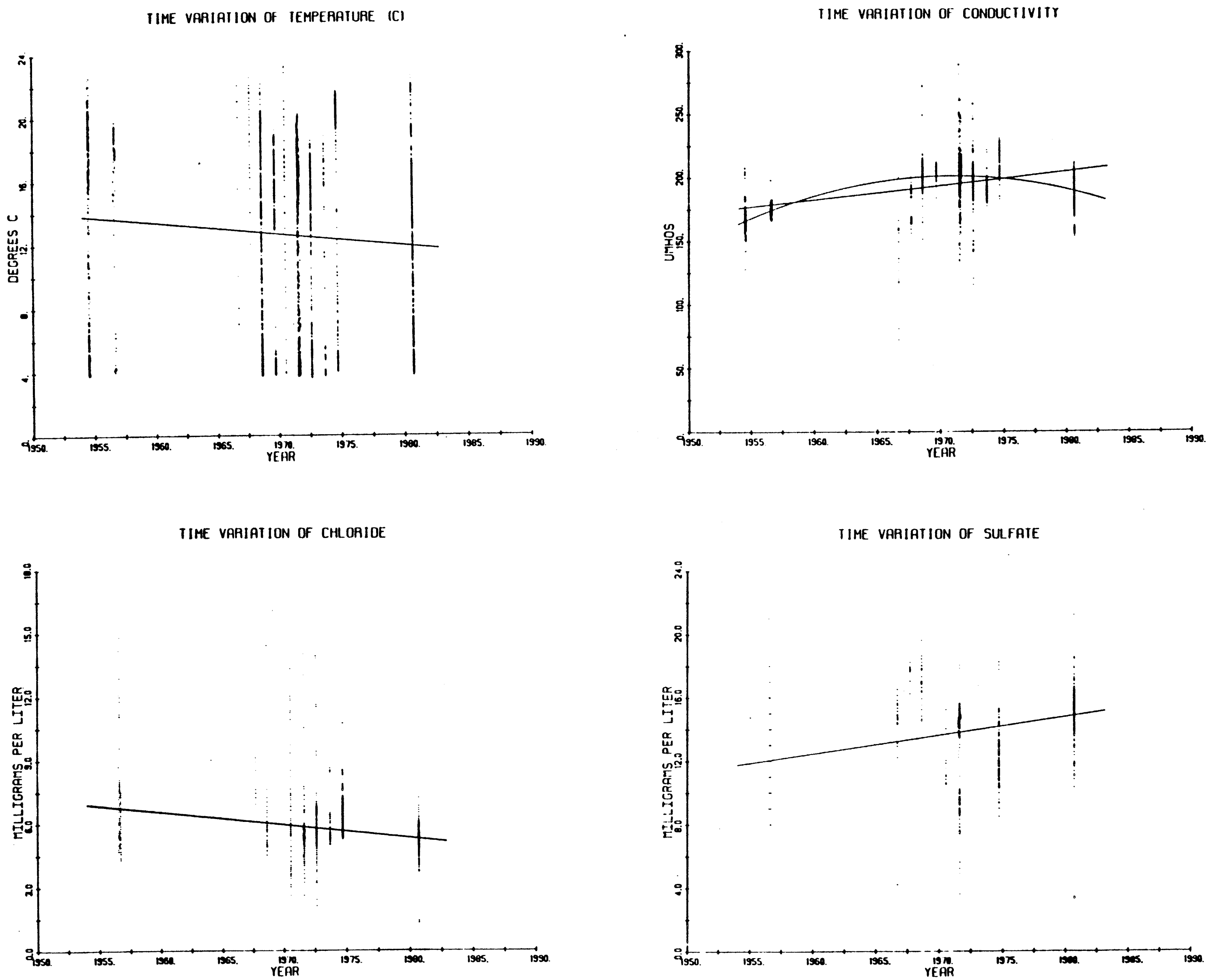



Figure 10. Summer time variation of parameters in Lake Huron water.

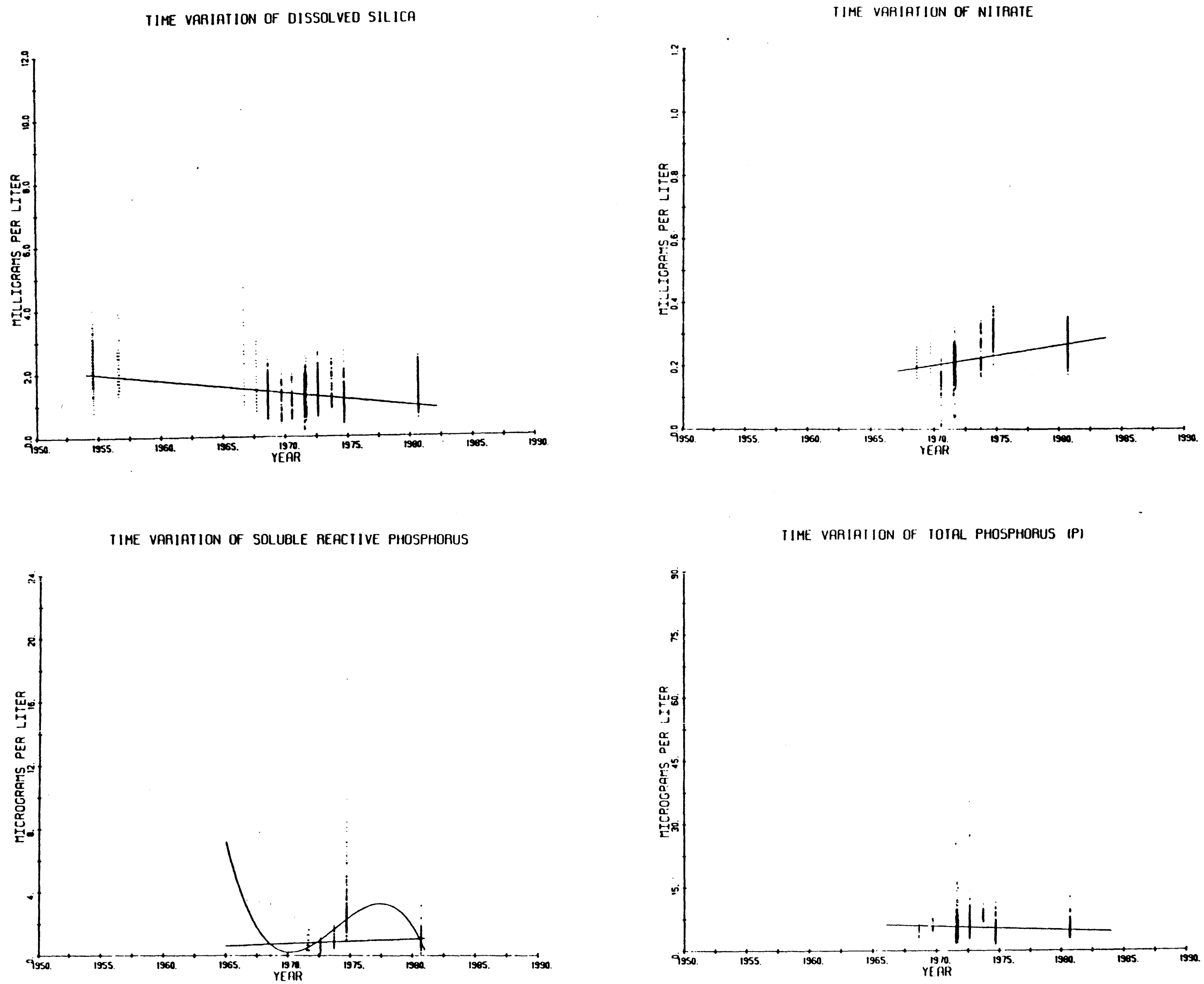



Figure 10. Concluded.

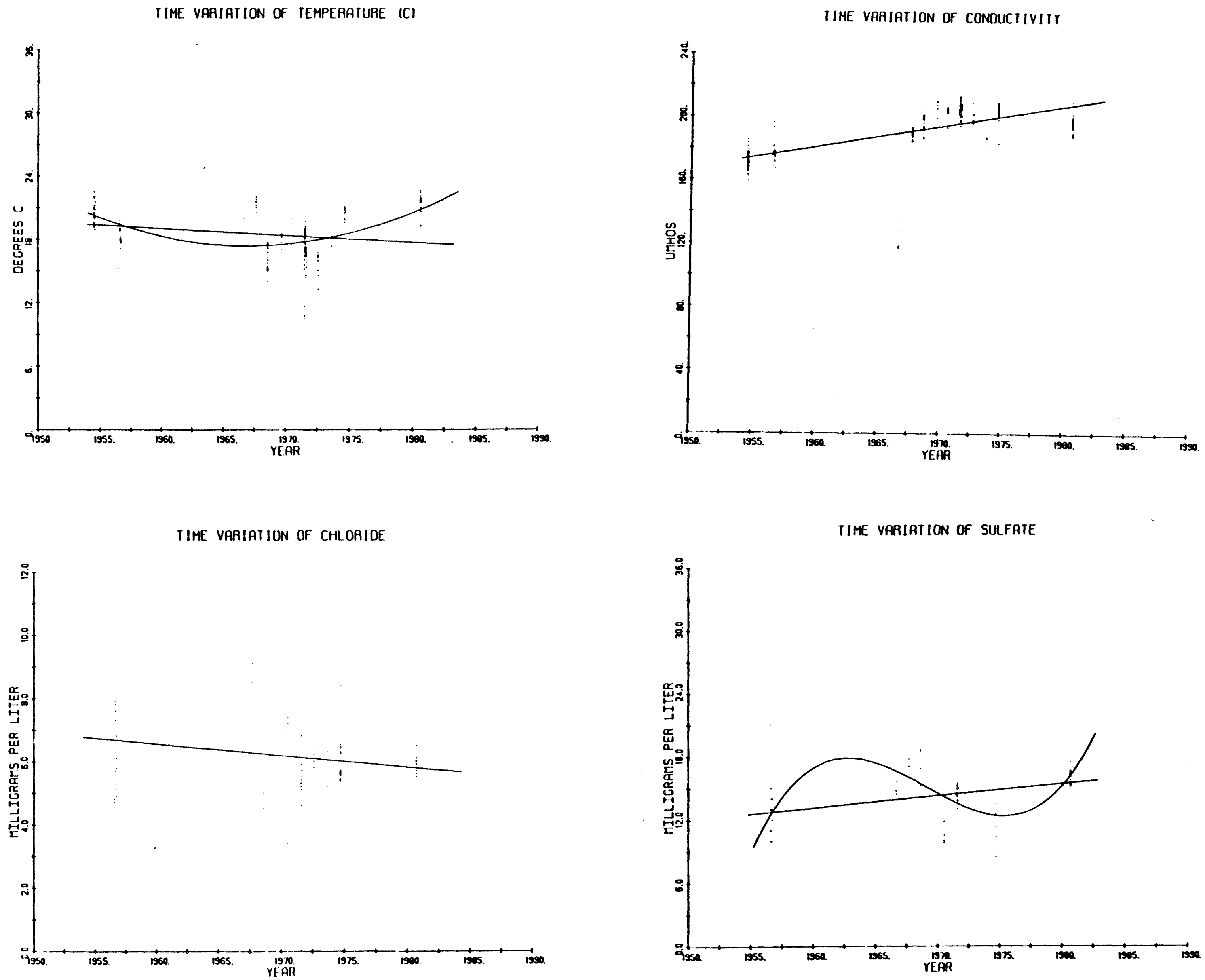



Figure 11. Summer time variation of parameters in one water mass for the Lake Huron epilimnion.

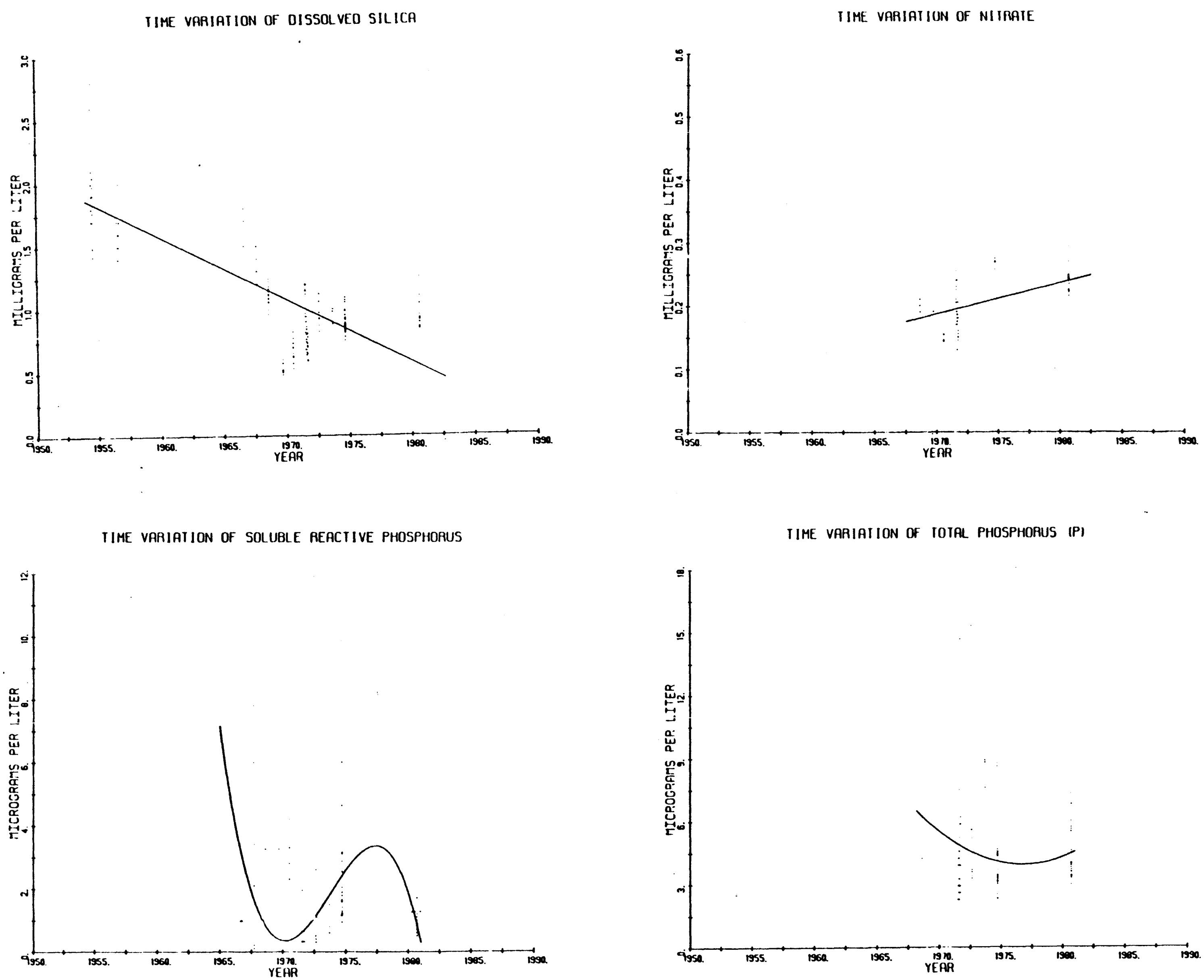



Figure 11. Concluded.

Fig. 10). Conductivity displayed a significant second-order variation (Fig. 10). It increased between 1954 and 1970 and decreased after 1970. Soluble reactive phosphorus displayed a significant third-order variation. It decreased between 1966 and 1970, increased between 1970 and 1977, and decreased after 1977.

Summer - One Homogeneous Water Mass

All eight variables changed significantly between 1954 and 1980 (Table 3). The regression coefficients derived from both the one water mass and the epilimnetic portion of the water mass were quite similar to those from the whole summer data set (Table 3). For the one water mass subset of data, all but total phosphorus displayed significant linear trends. The signs of the regression coefficients generated from either one water mass or the epilimnetic portion of the water mass were identical to those for all summer data. The magnitude of the coefficients was also very similar between these data sets. Like those of spring, the trends were small but statistically significant. For the summer epilimnion one water mass, linear trends were significant for temperature, conductivity, chloride, sulfate, dissolved silica, and nitrate (Table 3, Fig. 11). Four variables were best described by curvilinear fits (Fig. 11). Temperature decreased between 1954 and 1966 and increased after 1966. Sulfate increased between 1956 and 1962, decreased between 1962 and 1975, and increased after 1975. Soluble reactive phosphorus decreased between 1966 and 1970, increased between 1970 and 1977, and decreased after 1977. Total phosphorus decreased between 1968 and 1977 and increased after 1977. Lesht (1985) and Lesht and Rockwell (1985) reported that total phosphorus appears to have decreased significantly since 1980.

As reported by Moll *et al*. (1985), waters entering Lake Huron from Lake Superior are characterized by a high dissolved silica concentration and low conductivity and chloride concentration. Waters from Lake Michigan are characterized by low dissolved silica concentration and high conductivity and chloride concentration. Inputs along the north shore of Georgian Bay are characteristically of low conductivity and low chloride concentration (Moll *et al*. 1985). Inputs from Saginaw Bay to the lake are characterized by high conductivity and high chloride concentration. Moll *et al*. (1985) noted, as did Kwiatkowski (1982), high nitrate-nitrogen concentrations along the Ontario shore of southern Lake Huron, especially in the spring during the existence of a thermal bar. Moll *et al*. (1985) found particulate organic carbon to be high along the Ontario shore of southern Lake Huron, along the southern edge of outer Saginaw Bay, along the southern shore of the Straits of Mackinac, and in eastern Georgian Bay. They also concluded that the chlorophyll concentrations are characteristic of what is expected for this oligotrophic lake.

## SUMMARY

There was no apparent decrease in estimated total phosphorus loading to Lake Huron between 1976 and 1980. Uncertainties in components of the estimates and the relatively few years for which estimates are available may preclude the possibility of discerning any trend. Atmospheric phosphorus loading to Georgian Bay and the North Channel decreased in 1980 to its lowest level since 1977.

Long-term changes in the chemistry of Lake Huron waters have been identified using the results of 12 studies spanning a 26-year period of observations. As might be expected of a dynamic system, Lake Huron long-term trends are complex. For roughly one-half of the parameters investigated, changes over the

26 years were curvilinear or oscillatory. Of these, one-half had a linear trend superimposed over the oscillations. For each of the various ways we manipulated the data base, sulfate and nitrate were found to increase. For the majority of cases, dissolved silica and chloride decreased. Sulfate increased at a rate of 0.05 to 0.13 mg/L/yr or 0.3 to 0.8% of the 1980 mean concentration per year. Nitrate increased at a rate of 0.0030 to 0.0089 mg/L/yr or 1.1 to 3.1% per year. Dissolved silica decreased at a rate of 0.040 to 0.049 mg/L/yr or 2.8 to 3.6% of the 1980 mean per year. Chloride decreased at a rate of 0.02 to 0.06 mg/L/yr or 0.4 to 1.2% of the 1980 mean per year. Monitoring of all four parameters should be continued.

For those parameters which showed reversals in trend over the period of observation, reversals consistently occurred in the mid-1970s. It is unfortunate that data were not available for this critical period of time. Since the mid-1970s, dissolved reactive silica and soluble reactive phosphorus have decreased, and nitrate and sulfate have increased. Changes in long-term trends could be or have been attributed to factors such as changes in sampling and analytical methods, reduction in anthropogenic inputs from the major point sources, and differences in biological utilization of these elements. Despite the changes which have occurred in Lake Huron between 1954 and 1980, Lake Huron remains an oligotrophic lake.

# TRACE METALS

## WATER

Special metals studies by Rossmann (1982, 1983) are summarized in this section. Total silver concentrations were higher in the epilimnion than in the hypolimnion. Total cobalt concentrations exhibited no consistent vertical trend. In general, chromium concentrations were highest in the epilimnion. Total copper, manganese, iron, and arsenic were always highest at or above the thermocline. Metals consistently higher in concentration above the thermocline than below it are most likely high as a result of inputs to the lake. The horizontal distributions of total metal concentrations from month to month were quite variable. Iron was always highest in southern Lake Huron, and copper and manganese were highest in the North Channel for a limited number of observations (two out of three).

Total metals exhibited some variation with time. In a comparison of various regions of the lake, silver, arsenic, cobalt, chromium, copper, iron, and manganese were found to be highest in April 1980 in Georgian Bay. Metals showing a continuous decrease between April and July in Georgian Bay include silver, cobalt, copper, iron, and manganese. In the North Channel, arsenic and cobalt were highest in mid-May. Silver, chromium, and iron were lowest in July. In general, highest total metal concentrations occurred in April and May for most metals. This may be associated with the spring thaw and runoff.

The 1978 Water Quality Agreement objective for mercury (0.2 µg/L) was exceeded twice (8.8% of all samples) during 1980. This was most likely a result of sample contamination. The proposed objective for selenium was exceeded once (4.4% of all samples).

Because of inadequacies in the historical data base, the prediction of trace metal trends is difficult and subject to error. Improvements in instrumentation and methodology have lowered detection limits and the amount of sample contamination. Thus, metals which appear to be decreasing in concentration may appear so only because of the advancement of the science. The following changes in metal concentrations are to be considered only tentative. A number of metals appear to be decreasing in concentration (Table 4). These include dissolved arsenic, total cadmium, dissolved cadmium, dissolved copper, total lead, dissolved lead, total nickel, dissolved nickel, total zinc, and dissolved zinc (Table 4). Total cobalt and total vanadium concentrations appear to have increased (Table 4). Based upon the information presented here, any one metal concentration does not appear to pose any significant risk to the biota of the lake.

TABLE 4. Summary of probable metal concentration changes in Lake Huron water.

| Metal | Increase | Decrease | No Change | Not Discernible From Data |
|---|---|---|---|---|
| Al | | | | x |
| As | | x | | |
| Cd | | x | | |
| Co | x | | | |
| Cr | | | | x |
| Cu | | x | | |
| Fe | | x | | |
| Hg | | | | x |
| Pb | | x | | |
| Mn | | | x | |
| Ni | | x | | |
| Se | | | | x |
| V | x | | | |
| Zn | | x | | |

To estimate the potential toxicity of metal mixtures, the toxic unit concept as recommended and described in an Aquatic Ecosystems Objectives Committee (1980) report to the Great Lakes Science Advisory Board of the International Joint Commission was used. The recommended approach is to sum the ratios of each metal concentration ($M_i$) to its respective objective concentration ($O_i$). The sum should not exceed 1.0. Water Quality Agreement objectives and the calculated toxic units are summarized in Table 5. Except for mercury, all objectives are on the basis of total metal concentrations. Because the sum does not exceed 1.0, adverse ecological effects would not be expected. However, selenium contributes more than one-half of the toxic unit. Thus, selenium is a potential future problem.

TABLE 5. Toxic unit results for waters collected in 1980 from Lake Huron.

| Metal | Water Quality Objective ($O_i$)[1] | Observed Concentration ($M_i$)[1,2] | $M_i/O_i$ |
|---|---|---|---|
| Ag | 0.1 | 0.0090 | 0.090 |
| As | 50. | 0.21 | 0.0042 |
| Cd | 0.2 | 0.015 | 0.075 |
| Cr | 50. | 0.13 | 0.0026 |
| Cu | 5.0 | 0.40 | 0.080 |
| Fe | 300. | 4.8 | 0.016 |
| Hg | 0.2[3] | 0.0042 | 0.021 |
| Ni | 25. | 0.54 | 0.022 |
| Pb | 3.0 | 0.022 | 0.0073 |
| Se | 1.0[4] | 0.48 | 0.48 |
| Zn | 30. | 0.29 | 0.010 |
| Toxic Unit = $\left( \sum_{n=1}^{i} M_i/O_i \right)$ | | | 0.808 |

[1]Median (µg/L).
[2]Data from Rossmann (1982).
[3]Filtered sample.
[4]Recommended objective.

## SEDIMENT

Trace metal concentrations in sediments can be useful for documenting long-term trends. Unlike water data, reliable sediment data are available which predate the settlement of the Lake Huron basin. The results are derived from the analysis of sediment cores, which are dated using Pb-210. For Lake Huron, Robbins (1980) collected and analyzed numerous cores. These cores extended deeply enough to sample pre-settlement sediments. By comparing recent surficial sediment concentrations to pre-settlement concentrations, he calculated enrichment factors for numerous metals. He found manganese, cadmium, copper, lead, nickel, and zinc to be consistently enriched in surficial sediments. Elements which only occasionally showed enrichment in surficial sediments were iron, barium, and chromium. Those enriched in surficial sediments for which only a few cores were analyzed include arsenic, antimony, tin, mercury, and molybdenum.

Similar work by Kemp and Thomas (1976) comparing pre-colonial and recent sediments showed mercury to be very slightly enriched and lead, zinc, cadmium, and copper to be enriched.

The background concentrations used by Kemp and Thomas (1976) and Robbins (1980) are summarized in Table 6. Included within the table are metal concentrations for the basins of Lake Huron where sediments are accumulating (Konasewich _et al_. 1978). Comparison of data sets leads to the conclusion that cobalt, chromium, copper, mercury, nickel, lead, and zinc are accumulating in recent sediments at concentrations above historical levels. Because the metals Co, Mn, Cd, Cu, Pb, Ni, Zn, Fe, As, Cr, Sb, Sn, Hg, Ba, and Mo are enriched in recent sediments and because contaminants reach the sediments by transport through the water column, one should expect total metal concentrations in water for these elements to be increasing.

TABLE 6. Comparison of metal concentrations in recent Lake Huron sediments with those in older sediments (mg/kg).

| | Historical Concentrations | | Recent Sediments[2] | |
|---|---|---|---|---|
| Metal | Kemp and Thomas (1976) | Robbins (1980)[1] | Lake Huron Basins | Georgian Bay and North Channel Basins |
| As | | 6.0 | 1.88 | 7.19 |
| Cd | 1. | 1.6 | 1.3 | 2.01 |
| Co | | 12.2 | 17. | 24. |
| Cr | | 55. | 43. | 176. |
| Cu | 38. | 30. | 46. | 60. |
| Hg | 0.15 | 0.03 | 0.277 | 0.392 |
| Ni | | 35. | 51. | 119. |
| Pb | 39. | 30. | 66. | 67. |
| V | | 120. | 54. | 77. |
| Zn | 94. | 65. | 86. | 146. |

[1]Derived from his data.
[2]Konasewich *et al*. (1978).

## ORGANIC CONTAMINANTS

The following are taken from a detailed document prepared by Kreis and Rice (1985).

### NET PLANKTON AND FILAMENTOUS ALGAE

Reported measurements of organic contaminants in plankton and filamentous algae are very limited. No data exist for 1980. Among the contaminants reported for net plankton in 1979 were total PCBs and p,p'DDE. In 1974, traces of dieldrin were also found. Compared to plankton in the remainder of the lake during 1974, highest total PCBs were reported for southern Lake Huron and Georgian Bay. Organic contaminant data for filamentous algae are available only for 1979. These data are for the genera Cladophora and Ulothrix. Each contained measurable concentrations of total PCBs and p,p'DDE. Because of the sparsity of data, little can be concluded.

### FISH

Relative to the net plankton and filamentous algae data base, that for fish is large. A large number of organic contaminants have been found in Lake Huron fish. A summary of the years during which concentrations exceeded IJC allowable limits is contained in Table 7. Although no fish species showed a significantly increasing trend for PCBs, PCBs in fish continue to be a major lakewide problem. Only in Saginaw Bay was a significant decreasing PCB trend found for whole yellow perch. Fish from Saginaw Bay were found to have concentrations of PCBs significantly higher than those from any other region of the lake. Although the

TABLE 7. Summary of fish and years when organic concentrations were in excess of the International Joint Commission (IJC) allowable limits.

| Compound | Fish | Years |
| --- | --- | --- |
| PCB | | |
| | Carp | 1969-1980* |
| | Channel catfish | 1969-1980* |
| | Yellow perch | 1968-1979* |
| | Lake trout | 1969-1980* |
| | Bloater chub | 1969-1978* |
| | Lake whitefish | 1969-1976* |
| | Walleye | 1969-1980* |
| | Coho salmon | 1968-1980* |
| | Chinook salmon | 1973-1980* |
| | Brown trout | 1973-1980* |
| | Splake | 1969-1975* |
| | Rainbow trout | 1968-1975* |
| | Cisco | 1969-1976* |
| | Burbot | 1974* |
| | Northern pike | 1974* |
| DDT | | |
| | Carp | 1967-1972 |
| | Channel catfish | 1966-1972, 1979 |
| | Yellow perch | 1967-1968, 1970 |
| | Lake trout | 1969-1979 |
| | Bloater chub | 1966, 1970-1978* |
| | Lake whitefish | 1966, 1970 |
| | Walleye | 1966, 1969-1971 |
| | Coho salmon | 1971-1973 |
| | Chinook salmon | 1973-1974 |
| | Brown trout | 1973 |
| | Splake | 1969-1970, 1975* |
| | Rainbow trout | 1968-1970 |
| | Cisco | 1969, 1975 |
| | Burbot | 1974* |
| Dieldrin-aldrin | | |
| | Yellow perch | 1979* |
| | Lake trout | 1977-1979 |
| | Bloater chub | 1974-1975 |
| | Splake | 1975* |
| Mercury | | |
| | Walleye | 1973-1974, 1978* |

*Last year of analysis.

only statistically significant DDT-R trend found was that for decreased concentrations in Saginaw Bay yellow perch, DDT-R in Lake Huron fish appears to be a waning problem (1967-1979). For open-lake lake trout, whole yellow perch, whitefish, and walleye, DDT-R concentrations since 1973 were considerably lower than those prior to 1973. Within Saginaw Bay, fish collected from the vicinity of the mouth of the Saginaw River and near Bay City usually had the highest dioxin concentrations. Dioxin and furans appear to be an emerging problem requiring monitoring. Mean dieldrin concentrations were typically highest in fish collected from Alpena, Michigan, and Georgian Bay (1967-1980). The frequency of the aldrin-dieldrin sum exceeding the IJC objective (0.3 mg/kg) appears to be increasing. Continued monitoring is necessary. Mercury concentrations were highest in walleye from the northern portion of the lake and Georgian Bay. Some of the highest mercury concentrations in fish have been reported since 1973. The 3 years of analysis of walleye for Hg yielded concentrations in excess of the IJC objective (0.5 mg/kg). Additional monitoring is required. There is no evidence of decreasing mercury concentrations.

## HERRING GULL EGGS

Monitoring of herring gull eggs for contaminants began in 1974 (Fig. 12). Excluding the Manitoba Reef colony, which also had high PCB concentrations, colonies in Saginaw Bay in 1980 had PCB concentrations 2-4 times those of the remaining six colonies. In 1980, highest DDE concentrations were reported for the Channel/Shelter Island and Little Charity Island colonies in Saginaw Bay, the Black River Reef near Thunder Bay, and Manitoba Reef. In 1980, mirex was highest at Nottawasaga Island colony in southeastern Georgian Bay.

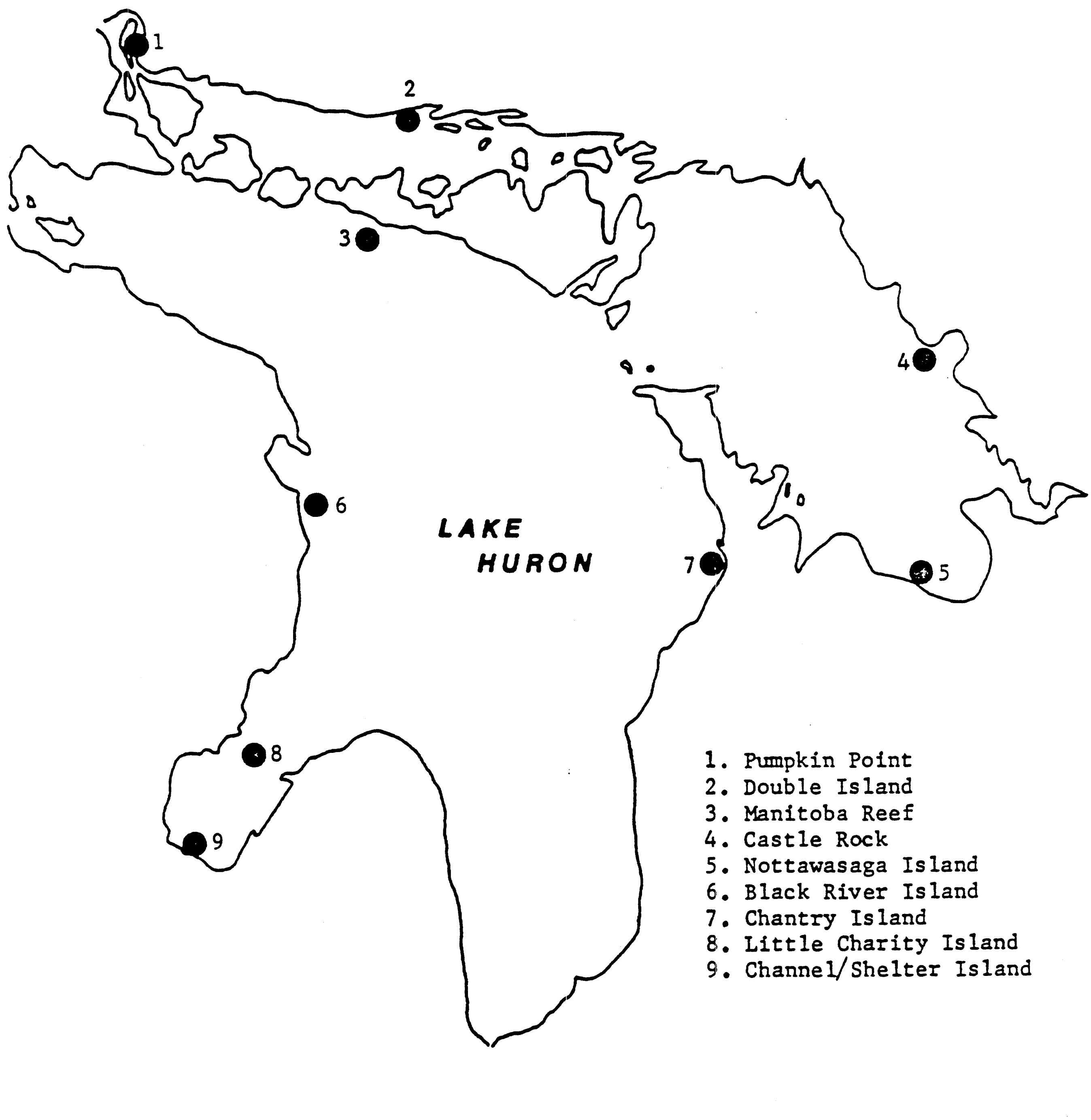



Figure 12. Lake Huron herring gull colonies monitored for contaminants.

Dioxin (2,3,7,8 TCDD) was considerably higher in 1980 in the Saginaw Bay colonies than in the Double Island colony in the North Channel.

Concentrations of PCBs and mirex in eggs from the Double Island and Chantry Island colonies have significantly decreased since 1974. Since 1974, DDT concentrations in Double Island eggs have significantly decreased. Concentrations of DDE have decreased in Chantry Island eggs since 1974.

## WATER

Years during which concentrations of organic contaminants exceeded the IJC objective levels are summarized in Table 8. The highest PCB concentration was reported for water collected near Harbor Beach, Michigan, in 1979. In 1980, concentrations in Saginaw Bay, Thunder Bay, and Harbor Beach waters exceeded the IJC objective. Similarly, mean concentrations for Georgian Bay and the North Channel waters exceeded the IJC objectives. All 1981 observations were below the IJC objective.

Table 8. Years during which organic compounds in Lake Huron water samples exceeded IJC recommended concentrations.

| Compound | Years |
|---|---|
| PCB | 1974, 1975, 1977, 1979, 1980 |
| DDT | 1974, 1975 |
| Dieldrin-aldrin | 1967 |
| Diethylhexyl phthalate | 1974, 1976* |

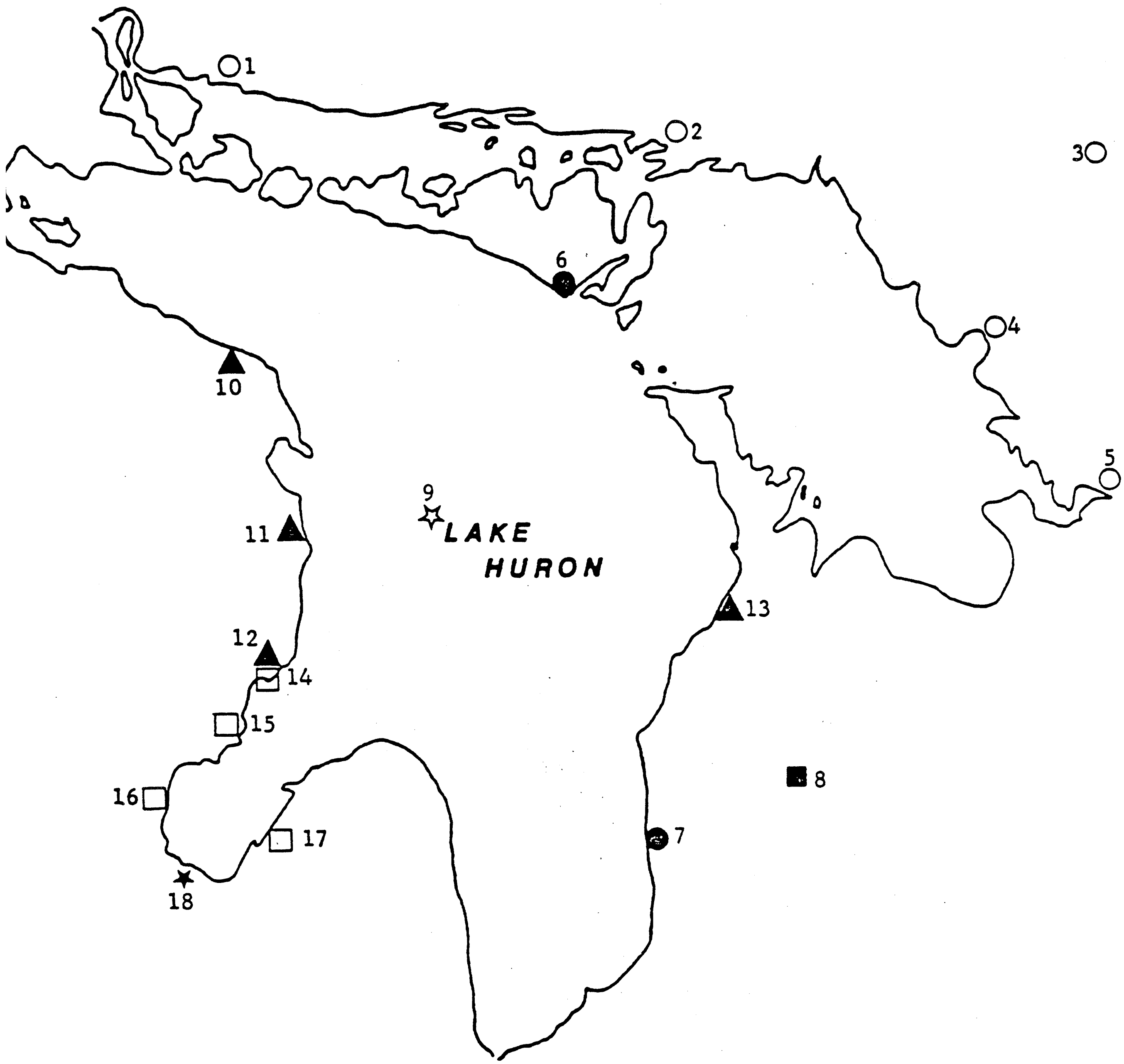
*Most recent year parameter was sampled.

## SEDIMENT

A number of conclusions can be made about contaminants in sediments for the period of 1969 through 1977. The highest PCB concentrations in sediments were found in Saginaw Bay. Main lake DDT-R concentrations were higher than those in Georgian Bay or North Channel sediments. In the main lake, PCB concentrations were highest in the Saginaw basin. Elevated concentrations were found in the nearshore region of Owen Sound and Collingwood harbor. During the period of 1957-1978, the highest DDT-R concentration was found in Saginaw Bay sediment. The highest dieldrin concentration was reported for Saginaw Bay in 1975. Georgian Bay had an elevated mean dieldrin concentration compared to the main lake and the North Channel. Mercury levels were similar in the main lake and Georgian Bay. The highest concentration was reported for Georgian Bay. Highest concentrations of DDE, DDD, DDT, DDT-R, and PCB were found at the tops of cores. Resolution for the cores was approximately 30 to 50 years. Thus, no recent trends could be inferred.

## ATMOSPHERE

Collection locations for atmospheric deposition are illustrated in Figure 13. Concentrations of PCB in precipitation at Pinconning were consistently higher than in those from Whitestone Point, Tawas Point, and Mount Forest. Highest PCB dry deposition and bulk deposition were also recorded at Pinconning. Other than PCBs, polychlorinated terphenyls (PCT) were detected in 1980; and alpha BHC, methoxychlor, lindane, DDT-R, dieldrin, endosulfan I, and endosulfan II, in 1976. No other organic contaminants were sought.




Strachan and Huneault (1979)
Snow
1. Thessalon
2. Espanola
3. Trout Creek
4. Parry Sound
5. Honey Harbor
Rain
6. South Bay Mouth
7. Goderich

Davis (1980)
8. Mount Forest

Williams (1981)
9. Six Fathom Bank

Mullin (1982)
10. Rogers City
11. Sturgeon Point
12. Tawas Point
13. Douglas Point

Murphy et al. (1982)
14. Tawas Point
15. Whitestone Point
16. Pinconning
17. Sebewaing

Rice (1981)
18. Bay City

Figure 13. Lake Huron atmospheric deposition collection sites.

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Appendix 1. Cruise dates for Lake Huron study.

| Cruise Number | Dates | Average Julian Day |
|---|---|---|
| Cruise One | | |
| Lake Huron | | |
| Southern Basin | April 13-15, 1980 | 104 |
| Northern Basin | April 15-20 & 23, 1980 | 108 |
| North Channel | April 20-21, 1980 | 110 |
| Georgian Bay | April 24-27, 1980 | 116 |
| Cruise Two | | |
| Lake Huron | | |
| Southern Basin | May 10-11, 1980 | 130 |
| Northern Basin | May 11-16, 1980 | 133 |
| North Channel | May 16-17, 1980 | 136 |
| Georgian Bay | May 18-21, 1980 | 140 |
| Cruise Three | | |
| Lake Huron | | |
| Southern Basin | May 28-29, 1980 | 148 |
| Northern Basin | May 29-June 4, 1980 | 152 |
| North Channel | June 4-5, 1980 | 156 |
| Georgian Bay | June 5-7, 1980 | 157 |
| Cruise Four | | |
| Lake Huron | | |
| Southern Basin | July 18-19, 1980 | 200 |
| Northern Basin | July 20-25, 1980 | 203 |
| North Channel | July 25-27, 1980 | 207 |
| Georgian Bay | July 27-30, 1980 | 210 |
| Cruise Five | | |
| Lake Huron | | |
| Southern Basin | Sept. 8-11, 1980 | 252 |
| Northern Basin | Sept. 11-15, 1980 | 256 |
| North Channel | Sept. 15-16, 1980 | 258 |
| Georgian Bay | Sept. 16-21, 1980 | 261 |

(Continued)

Appendix 1. Concluded.

| Cruise Number | Dates | Average Julian Day |
| --- | --- | --- |
| Cruise Six | | |
| Lake Huron | | |
| Southern Basin | Oct. 22-27, 1980 | 398 |
| Northern Basin | Oct. 27-31, 1980 | 302 |
| North Channel | Oct. 21-Nov. 1, 1980 | 304 |
| Georgian Bay | Nov. 2-4, 1980 | 307 |
| Winter Cruise One | | |
| Lake Huron | | |
| Southern Basin | Jan. 20-21, 1981 | 20 |
| Winter Cruise Two | | |
| Lake Huron | | |
| Southern Basin | Feb. 24-25, 1981 | 56 |

Appendix 2. Lake Huron surveillance stations for 1980 (see Figure 1).

| STATION NO. | LATITUDE | LONGITUDE |
|---|---|---|
| 1980 OPEN LAKE SURVEILLANCE STATIONS | | |
| 1 | 43°05'24" | 82°23'30" |
| 2 | 43°11'24" | 82°17'54" |
| 3 | 43°15'25" | 82°02'18 |
| 4 | 43°19'30" | 81°47'18" |
| 5 | 43°32'54" | 81°44'42" |
| 6 | 43°28'00" | 82°00'00" |
| 90 | 43°24'00" | 82°18'00" |
| 7 | 43°20'30" | 82°30'24" |
| 8 | 43°34'00" | 82°29'06" |
| 9 | 43°38'00" | 82°13'00" |
| 91 | 43°42'00" | 82°01'00" |
| 10 | 43°45'12" | 81°46'54" |
| 11 | 43°57'24" | 81°47'12" |
| 12 | 43°53'24" | 82°03'24" |
| 92 | 43°48'30" | 82°22'00" |
| 13 | 43°45'12" | 82°34'06" |
| 14 | 43°56'30" | 82°40'00" |
| 15 | 44°00'00" | 82°21'00" |
| 16 | 44°07'54" | 82°45'00" |
| 17 | 44°06'00" | 82°52'00" |
| 18 | 44°07'25" | 83°10'15" |
| 19 | 44°09'00" | 82°58'00" |
| 20 | 44°13'00" | 83°05'00" |
| 21 | 44°16'00" | 83°12'00" |
| 22 | 44°12'40" | 83°22'40" |
| 23 | 44°20'00" | 83°18'00" |
| 24 | 44°16'00" | 82°55'00" |
| 25 | 44°23'00" | 83°16'00" |
| 26 | 44°20'00" | 83°05'00" |
| 27 | 44°11'54" | 82°30'12" |
| 28 | 44°12'18" | 81°40'36" |
| 93 | 44°06'00" | 82°07'00" |
| 29 | 44°22'00" | 81°50'00" |
| 30 | 44°28'00" | 81°27'12" |
| 31 | 44°51'00" | 81°36'00" |
| 32 | 44°27'12" | 82°20'30" |
| 33 | 44°30'00" | 82°50'00" |
| 34 | 44°38'24" | 83°13'54" |
| 35 | 44°51'00" | 83°15'42" |
| 36 | 45°02'06" | 83°22'42" |
| 37 | 44°45'42" | 82°47'00" |
| 38 | 44°44'24" | 82°03'36" |
| 39 | 44°39'24" | 81°22'42" |
| 40 | 44°53'54" | 81°26'12" |

(continued)

Appendix 2. Continued.

| STATION NO. | LATITUDE | LONGITUDE |
|---|---|---|
| 41 | 45°05'00" | 81°32'18" |
| 42 | 45°13'18" | 81°49'12" |
| 43 | 45°00'48" | 82°00'30" |
| 44 | 45°01'00" | 82°41'06" |
| 45 | 45°08'12" | 82°59'00" |
| 94 | 44°04'15" | 83°05'00" |
| 46 | 45°04'48" | 83°14'00" |
| 47 | 45°15'18" | 83°20'48" |
| 48 | 45°16'42" | 82°27'06" |
| 49 | 45°24'48" | 81°55'06" |
| 50 | 45°32'06" | 82°02'42" |
| 51 | 45°32'00" | 82°16'48" |
| 52 | 45°39'06" | 82°38'54" |
| 53 | 45°27'00" | 82°54'54" |
| 54 | 45°31'00" | 83°25'00" |
| 55 | 45°23'30" | 83°39'06" |
| 56 | 45°31'00" | 84°05'00" |
| 57 | 45°40'00" | 83°43'36" |
| 58 | 45°52'06" | 83°16'00" |
| 59 | 45°46'00" | 83°01'42" |
| 60 | 45°54'06" | 83°31'06" |
| 61 | 45°45'00" | 83°55'00" |
| 62 | 45°40'30" | 84°11'12" |
| 63 | 45°42'12" | 84°30'42" |
| 64 | 45°48'48" | 84°45'18" |
| 65 | 45°50'42" | 84°34'00" |
| 66 | 45°51'48" | 84°17'42" |
| 67 | 45°56'06" | 83°54'00" |

(Continued)

Appendix 2. Continued.

| STATION NO. | LATITUDE | LONGITUDE |
|---|---|---|
| **1980 GEORGIAN BAY SURVEILLANCE STATIONS** | | |
| 101 | 44°43'03" | 80°51'24" |
| 102 | 44°48'30" | 80°52'18" |
| 103 | 44°43'30" | 80°37'00" |
| 104 | 44°38'45" | 80°10'00" |
| 105 | 44°47'48" | 80°14'36" |
| 106 | 44°44'12" | 80°26'06" |
| 107 | 44°53'20" | 80°17'50" |
| 108 | 44°57'10" | 80°08'06" |
| 109 | 44°52'18" | 79°58'05" |
| 110 | 45°03'45" | 80°11'28" |
| 111 | 45°55'15" | 80°36'21" |
| 112 | 44°55'12" | 80°52'30" |
| 113 | 45°01'36" | 80°52'36" |
| 114 | 45°08'20" | 80°31'24" |
| 115 | 45°10'00" | 80°17'48" |
| 116 | 45°21'13" | 80°29'12" |
| 117 | 45°14'42" | 80°52'30" |
| 118 | 45°09'10" | 81°04'03" |
| 119 | 45°04'00" | 81°15'14" |
| 120 | 45°13'00" | 81°13'36" |
| 121 | 45°21'54" | 81°11'24" |
| 122 | 45°28'50" | 80°50'15" |
| 123 | 45°33'35" | 80°36'38" |
| 124 | 45°40'44" | 80°50'20" |
| 125 | 45°46'40" | 80°45'15" |
| 126 | 45°50'00" | 80°54'00" |
| 127 | 45°52'00" | 81°00'00" |
| 128 | 45°42'12" | 81°05'24" |
| 129 | 45°35'00" | 81°05'00" |
| 130 | 45°32'30" | 81°22'00" |
| 131 | 45°14'18" | 81°26'24" |
| 132 | 45°16'12" | 81°35'00" |
| 133 | 45°22'13" | 81°35'06" |
| 134 | 45°27'10" | 81°43'46" |
| 135 | 45°31'39" | 81°40'10" |
| 136 | 45°42'30" | 81°37'12" |
| 137 | 45°43'00" | 81°22'30" |
| 138 | 45°53'00" | 81°06'30" |
| 139 | 45°52'24" | 81°15'30" |
| 140 | 45°51'52" | 81°32'08" |
| 141 | 45°56'00" | 81°31'04" |
| 142 | 45°54'46" | 81°35'42" |
| 143 | 45°49'52" | 81°47'19" |
| 144 | 45°58'20" | 81°41'55" |

(Continued)

Appendix 2. Concluded.

| STATION NO. | LATITUDE | LONGITUDE |
|---|---|---|
| 1980 NORTH CHANNEL SURVEILLANCE STATIONS | | |
| 68 | 46°02'30" | 83°51'12" |
| 69 | 46°04'42" | 84°01'42" |
| 70 | 46°08'12" | 83°40'18" |
| 71 | 46°14'00" | 83°44'48" |
| 72 | 46°13'36" | 83°35'24" |
| 73 | 46°11'12" | 83°21'18" |
| 74 | 46°08'54" | 83°12'04" |
| 75 | 46°05'00" | 83°25'00" |
| 76 | 46°00'00" | 83°26'00" |
| 77 | 45°58'12" | 83°11'54" |
| 78 | 46°02'06" | 83°00'00" |
| 79 | 46°07'24" | 82°53'09" |
| 80 | 46°00'00" | 82°51'21" |
| 81 | 46°04'42" | 82°44'36" |
| 82 | 45°56'18" | 82°45'30" |
| 83 | 46°00'00" | 82°33'00" |
| 84 | 46°05'30" | 82°33'24" |
| 85 | 46°06'00" | 82°25'30" |
| 86 | 46°00'18" | 82°23'18" |
| 87 | 46°03'40" | 82°11'50" |
| 88 | 46°03'20" | 82°00'00" |
| 89 | 45°55'00" | 82°09'40" |